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The primary goal of the Acquisition Review Quarterly (ARQ) is to provide practicing acquisition professionals with relevant management tools and information based on recent advances in policy, management theory, and research. ARQ addresses the needs of professionals across the full spectrum of defense acquisition, and is intended to serve as a mechanism for fostering and disseminating scholarly research on acquisition issues, for exchanging opinions, for communicating policy decisions, and for maintaining a high level awareness regarding acquisition management philosophies.

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THE USE OF ADVANCED WARFIGHTING EXPERIMENTS TO SUPPORT ACQUISITION DECISIONS

Kenneth Strayer, Thomas Hoivik, and Susan Page Hocevar

This article summarizes research conducted to determine the use of Advanced Warfighting Experiments to support material acquisition decisions. Specifically, the research evaluated the effectiveness of the Army Task Force XXI Advanced Warfighting Experiment (TF XXI AWE) objective of providing information to support investment decisions and refinement of requirements for emerging technology initiatives. Data were collected from appropriate program offices and user representatives to determine the perceived utility of the recommendations and level of implementation. Subjective data detailing why specific recommendations were or were not implemented were used to determine the contributing factors to a program's ability to benefit from participation in the experiment.

From March 1996 through October 1997, the Army conducted the Task Force XXI Advanced Warfighting Experiment (TF XXI AWE), culminating with a live exercise at the National Training Center, during Rotation 97-06, March 1997. The purpose of the AWE was to provide sufficient data to validate digitizing the battlefield and support credible assessments on which to base future procurement decisions. The TF XXI AWE was meant to be a tool for resolving issues and reducing risk early in the program development process and determining the adequacy of requirements, design, and new system capabilities before committing major resources. A total of 93 TF XXI emerging technology initiatives were initially included in the AWE.

The stated TF XXI AWE objectives include experimenting with advanced technologies and providing information to support investment decisions on the most promising initiatives (Department of the Army, 1996). The AWE was also meant to help the U.S. Army Training and Doctrine Command (TRADOC) refine requirements and develop solutions for Force XXI. The

final Live Experiment Assessment Report, prepared by the U.S. Army Operational Test and Evaluation Command (OPTEC), included full assessments of most participating TF XXI initiatives. OPTEC provided observations and specific developmental recommendations for each initiative (Department of the Army, 1997).

AWE as a Formative Evaluation Process

Advanced Warfighting Experiments are limited in their ability to predict real-world outcomes, since experimental data generally comes from single or few unrepeatable events. Safety restrictions, lack of realism, and unknown composition of future threats make AWE's weakly predictive at best. But experimentation is not limited to the rigorous demands of summative testing; it includes discovery learning. Experiments can be viewed as "formative exercises to see what works and what doesn't" (Lickteig, 1996, p. 15). The U.S. Army Research Institute recommended that the Army implement a formative evaluation method that focuses on exploration, explanation, and improvement. Formative studies are defined as "evaluative activities undertaken during the design and pretesting of programs to guide the design process" (Rossi, 1993, p. 104). Formative evaluations are conducted in developmental stages to help form or improve the system for the user (Lickteig, 1996).

Researchers at the RAND Corporation have demonstrated that the "credible uses" (CU) framework (Dewar, Bankes, Hodges, Lucas, Saunders-Newton, and Vye, 1996), based on a decision-to-experiment ladder (DEL), can improve the experimental results from an AWE (Lucas, Banks and Vye, 1998; Lucas, Moore, and Vye, 1998). This approach requires significant upfront analysis to link the experimental design to critical programmatic decisions. The decision-to-experiment ladder includes: issues, decisions to be made, argument to support the decisions, hypotheses to be adjudicated, experiments to resolve hypotheses, and analysis and measures to implement decisions (Lucas, Banks, and Vye, 1998). Examples of the ways in which the DEL can support formative assessments follow:

- The CU process requires that specific decisions be identified that can be resolved by experimentation. Specificity in stating focal issues is an initial requirement to experimental design (Lucas, Moore, and Vye, 1998).

- Through understanding the decisions to be made, analysts know exactly the strength of the argument needed to make the decision. This identification of arguments to support decisions is critical in the design of the experiment and is much more productive than conducting the experiment and then deducing what can be inferred from the evidence (Lucas, Banks, and Vye, 1998).

- For the experiment to be used credibly, it must be designed to support decisions. Because of the limited data gathered from AWEs, there must be an "objective and traceable link from experimental results to decisions on important issues" (Lucas, Banks, and Vye, 1998, p. 16).

Rossi (1993) provides additional support for the importance of the formative component of experiments. He argues that, no matter the complexity or integrity of the scientific process of the exercise, the worth of evaluations must be judged by their utility. To achieve maximum benefit from experiments, the actual evaluation must be tailored to the specific program, the stage of activity in the program, and the needs of the stakeholders in the program. Rossi (1993) outlines five factors that affect the utilization of evaluation findings: relevance to the problem, communication between researchers and users, information processing by users, plausibility of research results, and user involvement or advocacy.

The assessment of the utility of data from the TF XXI AWE to Army program managers is the central point of investigation in this research. In particular, OPTEC provided specific recommendations for each participating emerging technology initiative in its Live Experiment Assessment Report. These recommendations detailed changes to user requirements, desired technology improvements, and integration issues. This research evaluates the utility of the AWE to program mangers by investigating the levels at which these recommendations were implemented. Specific factors affecting utilization are identified to improve the formative benefits of future AWEs.

Research Methodology

The research methods were designed to evaluate the effectiveness of the TF XXI AWE objective of providing information to support investment decisions and refinement of requirements for information age technologies. The methodology included: creation of tailored surveys for each program initiative and dissemination to each applicable program office and user, and followup interviews of pertinent program managers, users, and test officials. The primary research questions addressed were:

"...no matter the complexity or integrity of the scientific process of the exercise, the worth of evaluations must be judged by their utility."

- Were the specific recommendations derived from the Task Force XXI AWE used to support investment decisions and to refine requirements of participating initiatives?
- What were the contributing factors to a program's ability to benefit from participation in the AWE?
- What are the characteristics of programs that are best positioned to gain valued investment and requirements information from participation in AWE?

A statistical analysis of collected data was conducted to evaluate implementation of initiative recommendations and to identify contributing factors to a program's ability to benefit from participation in the AWE. Additionally, a summary description of the characteristics of a program that is best positioned to participate in future AWEs was developed.

The scope of this research was limited to the 1997 TF XXI AWE. The research primarily concentrated on material acquisition issues, the immediate use of OPTEC recommendations for initiative development, and the contributing factors behind the use or non-use of those recommendations. Of the 93 emerging technology initiatives included in the experiment, 36 initiatives were included in the research. Certain initiatives were excluded from the research for the following reasons:

"The survey was designed to collect both objective and subjective data."

- the initiatives were not evaluated by OPTEC during the AWE;
- OPTEC did not provide any substantive recommendations by which to measure implementation;
- the initiative was a doctrinal or organizational change with no material program; or
- the program was subsequently terminated after the AWE and no representatives could be found to provide input towards the research.

Two representatives from each of the 36 emerging technology initiatives were sought for participation. First, program managers were identified based on their direct experience with the AWE and their ability to provide programmatic insights into the process and results of the AWE. Secondly, a user representative was identified, in most cases the combat developer responsible for the program. Of the 72 possible representatives, 67 were actually selected to participate in this study.

Survey Design

The survey was designed to collect both objective and subjective data. The objective survey items assessed the specific level of implementation of recommendations made in the Live Experiment Assessment Report. Subjective items were included to gather perceptions and opinions from specific program offices and user representatives. The subjective items were structured from the RAND Corporation's CU framework (Dewar et al., 1996) and the decision-to-experiments ladder (DEL) that directly links experiments to decisions (Lucas, Moore, and Vye, 1998). Specific survey items were framed on the decision-to-experiment ladder to allow participants to demonstrate through their responses the extent to which this decision ladder was implemented during the AWE.

Survey Instrument

The survey instrument utilized a combination of ordinal measurements reflecting the level of implementation achieved for each OPTEC recommendation and factors affecting implementation, as well as open-ended questions designed to gain subjective perceptions about the AWE process. The survey contained four sections.

Section 1 asked respondents to rate the level of implementation of the specific recommendations made for their program initiative by the Army OPTEC's Live Experiment Assessment Report. Participants

were asked to indicate the term that best described the extent that the recommendation was implemented: fully, mostly, limited, not at all. Participants were also asked to provide narrative comments explaining the factors that influenced the degree of implementation.

Section 2 contained questions about the program's experiences in the 1997 TF AWE that were derived from the decision-to-experiment ladder (Lucas, Moore, Vye, 1998). The questions covered all of the applicable components from issue development to analysis and implementation. Participants were asked to rate the following three questions using a five-point scale (with 1 being low, 5 being high):

- To what extent were you able to tailor or influence your program's specific activities in the AWE to relate to the issues and decisions you faced as an acquisition manager?

- How valuable were the data and recommendations gained from participation in the AWE in making decisions as an acquisition manager?

- To what extent did your program benefit from participating in the AWE?

Respondents also were asked to give a brief narrative explanation of each rating. In addition to the objective ratings, the following three open-ended questions were included to gather contributing factors and characteristics of programs best positioned to benefit from AWEs:

- What were the specific developmental ISSUES being addressed on your program at the time of its participation in the AWE and what decisions were to be made from gathered data?

- What were the contributing factors to your program's ability to benefit from participation in the AWE?

- Based on your program's experience in the 1997 AWE, describe the characteristics of a program that would best be situated to benefit from participation in a future AWE.

Section 3 gathered respondent opinions on reasons why recommendations made by the 1997 AWE were or were not fully implemented. The questionnaire attempted to include an exhaustive list of potential impediments or positive factors for implementation. Participants were asked to rate each of the items on a five-point scale (1, not significant; 5, highly significant). Examples of reasons for less than full implementation included: lack of money; lack of time; questionable validity of test data and recommendations; and technical feasibility. Examples of factors supporting implementation included: high priority by users, high priority of program office, available funding.

"The questionnaire attempted to include an exhaustive list of potential impediments or positive factors for implementation."

Section 4 asked respondents to provide any additional comments on their program's participation in the AWE, including any information that might assist acquisition managers in gaining maximum benefit from participation in future

experiments or that would assist planners in tailoring future experiments to better benefit participating programs.

INTERVIEWS

Finally, interviews were conducted with nine program representatives in order to solicit more detailed information addressing some of the questions in the survey. Examples of questions included in the interview are:

- How did your program benefit from participating in the AWE?
- What kind of specific feedback did you receive on your program's performance in the AWE? Was it valid? Could you take advantage and utilize the feedback?
- How did the maturity of your program affect its performance at the AWE?
- Were you able to tailor the analysis plan for your program with OPTEC?
- What risks were involved with participating in the AWE? How were those risks mitigated?
- How would you characterize a program that would stand to significantly benefit from participation?

RESPONDENTS

Sixty-seven surveys were administered to both program managers and user representatives of 35 different AWE initiatives. A total of 38 respondents returned completed surveys for a response rate of 56.7 percent. Military respondents ranged from major (O-4) to colonel (O-6) and had an average of 1.9 years experience on the program in question. Civilian respondents ranged from GS-12 to GM-15 and had an average of 7.5 years experience on their programs. The minimum amount of time any respondent had with their program was 12 months. Also included were four civilian contractors who directly supported program offices or user agencies.

ANALYSIS STRATEGY

The analysis methodology included a review of the respondent surveys to identify the following:

1. The average level of implementation of all included initiative recommendations.
2. The overall perception of the program's ability to tailor or influence the initiatives specific activities in the AWE.
3. The overall perceived value of the data and recommendations gained from participation in the AWE as acquisition managers.
4. The overall perceived benefit gained from participating in the AWE.
5. The relationship between degree of implementation of recommendations and factors such as program maturity, program tailorability, perceived value of the data and perceived benefit received from the AWE.
6. A hierarchy of reasons why recommendations were or were not fully implemented.

To address these analytic questions, arithmetic means, medians, and modes were computed for each rated question to determine relationships and effects. A confidence interval was computed that should include the true value of the parameter 95 percent of the time. For most analyses, medians were used for comparison so that outliers would not have a significant impact on results. Median results for the various collected factors were compared against one another and analyzed to determine trends and overall effects on the ability to benefit from the AWE. The Kruskal-Wallis method was used to test the equivalence ($p < .05$) of the various factor medians. Finally, the collected subjective comments were analyzed to draw conclusions to answer the primary and secondary research questions and develop a characteristic description of programs that are best positioned to gain valued investment and requirements information from participation in AWEs.

RESEARCH FINDINGS

USE OF RECOMMENDATIONS TO SUPPORT INVESTMENT DECISIONS

The specific recommendations derived from the TF XXI AWE were used to support investment decisions and to refine requirements of participating initiatives in some cases. Overall, programs reported that 52 percent of the OPTEC recommendations from the AWE Live Assessment Report were either fully or mostly implemented. Thirty percent of recommendations were not implemented at all. Respondents indicated only a moderate benefit from participating in the AWE and that the data and recommendations received were only somewhat valuable. The most cited reason for recommendations not being implemented was a lack of funding. The recommendation was most likely to be implemented if it was a high priority of the user. Participants considered data valuable in making decisions when the data met at least one of three requirements. First, the data provided actual user feedback on specific user requirements. Second, the data contributed to the development of tactics, techniques, and procedures. Third, the data were provided at a time when it could be instrumental in refining requirements and design.

"A wide range of confounding factors effected an initiative's ability to benefit from the AWE."

CONTRIBUTING FACTORS TO A PROGRAM'S ABILITY TO BENEFIT

The survey data showed that the level of recommendation implementation and the perceived level of benefit from the AWE were generally related. It cannot be concluded, however, that the implementation of AWE recommendations was solely responsible for a respondent's perception of benefit. A wide range of confounding factors effected an initiative's ability to benefit from the AWE.

In determining the contributing factors to a program's ability to benefit from AWE participation, a program manager must first define the term benefit, as it relates to his program. Program managers reported the following potential benefits from their TF XXI AWE participation:

- marketing and exposure of program;
- early user feedback;
- refinement of user requirements;
- development of tactics, techniques, and procedures (TTP);
- follow-on support for funding and production decisions;
- information on integration, interfaces, and interoperability; and
- exposure of developers to the user's environment.

Linkage Between AWE Design and Program Issue or Decision. Survey results found that those program managers who could provide a detailed explanation of the specific programmatic issues being addressed by their participation in the AWE or the decisions to be made from gathered data, generally reported a much higher level of perceived benefit from the experiment. Those programs that specifically developed test objectives and measurement processes for the AWE that were linked to specific acquisition decisions, were better positioned to benefit from participation.

"Survey comments indicate a substantial risk to programs participating in an AWE."

Tailoring of AWE Participation. The extent a manager was able to tailor or influence a program's specific activities in the AWE to relate to the program's acquisition issues and decisions directly contributed to the extent that the program benefited from participation. Those initiatives reporting a high level of ability to tailor or influence generally reported much higher levels of perceived benefit from participation in the AWE. Both program managers and user representatives agreed that to achieve maximum benefit from AWEs, acquisition managers must be able to participate in the planning process.

Program Maturity. Program maturity has an impact on an initiative's ability to benefit. While programs at all levels of maturity can gain from AWE participation, initiatives in the mid-range of development are best positioned to benefit. These programs are sufficiently mature and rugged enough to tolerate the harsh environment of AWEs, have architectures that are not yet finalized, and can make the most use of information derived from participation.

Risk Assessment. Survey comments indicate a substantial risk to programs participating in an AWE. Program risks include factors beyond the costs of participation, to include a poor return on investment, potential negative exposure, and extensive changes in requirements. The factors contributing to risk include: maturity, ruggedization and maintainability, funding availability, equipment availability, and status of program and production decisions.

RECOMMENDATIONS

As a result of the research analysis, we make the following recommendations for acquisition managers and AWE planners.

Acquisition Managers

Formulation of Objectives and Measurements. To maximize the potential to benefit from AWE participation, acquisition managers should develop objectives, measurement processes, and data documentation and analysis strategies for the AWE that will inform product improvements and areas for future investment. The results of AWE participation should be adequately documented to allow the use of AWE derived information and findings throughout the developmental life cycle of the participating program.

Participation in the Planning Process. To achieve maximum benefits from the AWE, acquisition managers should actively participate in the AWE planning process and tailor their program's activities in the AWE to relate to the issues and decisions facing the program. Data collection and analysis plans should also be tailored to ensure that the information derived from AWE participation is of value to the program.

Risk and Benefit Comparison and Analysis. Acquisition managers contemplating participation in future AWEs should conduct a detailed analysis of the risks associated with AWEs and consider their tolerance for risk as a factor in making a decision to participate. Potential risks should be compared to potential benefits from participation and interpreted to determine the best course of action for the program. Active measures should be identified to mitigate the specific risks associated with AWE participation. Methods to mitigate risk include:

- early budgeting of funds for the AWE;
- marketing to the user;
- assuring AWE users are adequately trained in the focal technology; and
- direct participation in the AWE planning process.

AWE Planners

Acquisition Manager Involvement. For the Joint Contingency Force (JCF) AWE, OPTEC representatives should meet with program managers to determine issues that are linked to AWE objectives (Department of the Army, 1998). Planners for future AWEs should allow acquisition managers to actively participate in the development of AWE goals and objectives, scenarios, and data collection and analysis plans so that the information derived from AWE participation is of value to the program.

"Potential risks should be compared to potential benefits from participation and interpreted to determine the best course of action for the program."

AWE Funding. The Army should consider providing funding for AWE initiatives so that acquisition managers can increase the benefits derived from participation. Participation in AWEs requires expensive prototyping, manning, fielding, training, and transportation costs that must be drawn from existing research and development accounts. Program managers cannot increase their roles in the AWE process and ability to tailor activities without dedicated support from the Army's budgetary process.

AWE Program Selection Criteria. The following factors should be considered when evaluating a program's potential to

gain valued investment and requirements information from participation in AWEs:

- **State of the Technology and Goals of the AWE.** Programs positioned to receive the most benefit from AWE participation will fit within the published goals, objectives, and focus of the AWE as stipulated by the planning officials. Also, the AWE must address the issues facing the initiative. As demonstrated in the TF XXI AWE, those programs that are not a high priority of the analyzing agency may not receive adequate feedback. Additionally, initiatives that are new concept technologies without established current tactics, techniques, and procedures are best positioned to benefit from the integration of multiple systems in an experimental environment.

"Programs in early in development are high risk because of their unpredictability and vaguely defined roles and requirements."

- **The Ability to Tailor Program Participation.** The extent a manager was able to tailor or influence a program's specific activities in the AWE to reflect the program's current acquisition issues and decisions had a direct impact on the extent to which the program benefited from participating. Those initiatives reporting a high level of ability to tailor or influence generally reported much higher levels of perceived benefit from participation in the AWE.

- **Program Participation Objectives and Strategies.** The data suggest that those program managers who develop detailed experiment objectives and expected outcomes, systems for data documentation and analysis, and strategies for implementation of AWE data and recommendations will receive more valued data and will experience more benefit from AWE participation.

- **Program Maturity.** Program maturity effects the ability of a program to perform adequately as well as the ability of the initiative to implement recommendations derived from the AWE. Programs in the mid-developmental phases of acquisition are best positioned to benefit from AWE participation. Programs in early in development are high risk because of their unpredictability and vaguely defined roles and requirements. Programs late in development or in production are medium risk because they may be to far in development to capitalize on recommendations.

Additionally, programs with no pending production or funding decisions are best positioned to benefit from AWE participation. Programs that have secured approval and funding for production prior to participation in an AWE but have not yet begun production, face the added risk of poor performance and loss of support. Those initiatives with imminent production decisions are medium risk, in that AWE performance can significantly influence the survivability of the system.

- **System Ruggedization and Maintainability.** Systems participating in AWEs should be ruggedized and easily maintainable. A system that is highly rugged is able to withstand the stresses associated with operational use in harsh environments. A system that scores low in ruggedization has sensitive components with maintenance procedures that are difficult to conduct in a field environment. Low ruggedization may be associated with early prototype systems.

- **Program Data Needs and Requirements**. Programs with extensive need for data on integration, interfaces, interoperability, and user requirements are best positioned to benefit. Those programs early in Concept Exploration would have the added benefit of receiving early data and user feedback to refine system requirements. Those programs with sufficient feedback from other sources, or not in a position to implement any recommendations from the feedback cannot take full advantage of AWE results and data.

CONCLUSION

The conduct of AWEs has provided unique insights into the future of Army Warfare and the potential acquisition of participating programs and weapon systems. However, the use of the data and recommendations generated to support acquisition decision making can and should be increased. The findings of this research strongly reinforce the principles of formative evaluation as outlined by Rossi (1993) and the Credible Uses Framework (Lucas, Banks and Vye, 1998) that links experimental design to explicit programmatic decisions.

Key factors were identified that can enhance the utility of AWE to programs responsible for the acquisition and development of technical systems. AWE planners can enhance the utility of resulting data to program managers by attending to specific criteria for program participation, involving program managers in the experimental planning, and providing financial support for AWE participation. Program managers participating in AWE can also take steps to increase the utility of results through specification of issues and decisions that can benefit from data generated by the experiment, a clear assessment of both benefits and risks, and active engagement in the design of measures. Future AWEs should focus on programs that can utilize the information most effectively. Additionally, appropriate funding should be provided to program participants to increase their ability to benefit from AWEs.

Kenneth Strayer, Captain, USA, was commissioned as an officer in 1990. He has served in a variety of combat arms assignments including service at the National Training Center (NTC), Fort Irwin, CA, and in the 25th Infantry Division (Light), HI. He holds a BS in Mechanical Engineering Technology from the University of Dayton, OH (1990), and an MS in Management from the Naval Postgraduate School (NPS), Monterey, CA (1999). He is currently serving in the Army Acquisition Corps with the Tank-Automotive and Armaments Command (TACOM), Research, Development, and Engineering Center (TARDEC).

(E-mail address: strayerk@acom.army.mil)

Thomas H. Hoivik, Captain, USN (Ret) is a professor of Operations Research at the Naval Postgraduate School (NPS) in Monterey, CA, specializing in high technology program management, systems engineering, and test and evaluation. A former experimental test pilot, he has been a Navy aircraft Program Manager, Director, U.S. Naval Test Pilot School, commanded a major Naval Air Base and Squadron, and was a Federal Executive Fellow at the Center for Strategic and International Studies (CSIS). He has over 30 years of Technical Program Management, Testing, and Systems Analysis experience, and has been teaching at NPS since 1983.

(E-mail address: thoivik@nps.navy.mil)

Susan Page Hocevar received her Ph.D. in Business Administration from the University of Southern California. She is currently an Assistant Professor in the Department of Systems Management at the Naval Postgraduate School in Monterey, CA. There she teaches courses in organization and management to military officers earning a graduate degree. Her research and publications are in the areas of organization change, high involvement organizations, reward systems, organizational culture and team-based organization design. Her current work is with an Office of Naval Research sponsored research effort in Adaptive Architectures for Command and Control.

(E-mail address: shocevar@nps.navy.mil)

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MEASURING THE READINESS COST OF ONE-SIZE-SHOE-FITS-ALL PUBLIC POLICY: *A LOOK AT COST-, HYBRID-, AND PRICE-BASED PURCHASING*

Maj Joseph Besselman, U.S. Air Force, Ashish Arora, and Patrick Larkey

Analysis of these three types of purchasing—price-, cost-, and hybrid-based—shows that a slight tweaking of current policy may produce better results, more in line with commercial buying practices.

The Department of Defense's (DoD's) Acquisition Reform team has fostered many promising reforms during the latter part of the 1990s, including the use of commercial standards, performance-based requirements, integrated product development, cost as an independent variable (CAIV), and greater use of price-based purchasing. While definitive evaluative studies do not yet exist on the effects of these various reforms, the preliminary evidence suggests that greater use of price-based purchasing has been a mixed blessing. The reform has apparently saved the DoD a great deal of money when used to buy commodities in markets where real competition exists. However, reformers have pushed price-based purchasing into the purchase of custom, noncommercial items produced under noncompetitive conditions, where price-based purchasing may not be the cost-minimizing approach.

The problem with implementing such a far-reaching policy, in general, is that without careful measurement, unintended consequences could occur and go largely undetected. The DoD, and the federal government more generally, have oversight organizations that investigate implementations of specific policies on an *ad hoc*

The views expressed in this paper are those of the authors and not the official views of the United States Air Force or Carnegie Mellon University.

basis. The DoD Inspector General (IG) has done at least four audits of the price-based purchasing policy since 1997, uncovering evidence of widespread overpayment by the government for custom, noncommercial items (see referenced DoD IG audit reports, 1998–99]. The IG's contrary evidence is all that is available on these acquisition innovations because the DoD has not systematically measured the performance of different purchasing policies.

The unintended consequence of these policies, price-based purchasing and a lack of systematic measurement, is that the warfighter may be adversely affected through higher prices. With essentially fixed budgets, higher spare part prices translate into fewer spare parts, less fuel, fewer training missions, and an overall weaker readiness posture. The readiness posture of U.S. forces is inextricably linked to the performance of the DoD's acquisition practices, including the purchase of spare parts. The warfighter currently takes for granted what the acquisition processes produce by not imposing rigorous organizational measures tying acquisition performance to readiness posture.

"The readiness posture of U.S. forces is inextricably linked to the performance of the DoD's acquisition practices, including the purchase of spare parts."

This research examines the purchase of noncompetitive spare parts for *exactly* the same engine bought by three different organizations using cost-, price-, and hybrid-based purchasing. The Federal Acquisition Regulations (FAR Part 15) provide considerable guidance on cost- and price-based purchasing and allude to various possibilities for hybrid purchasing schemes depending upon specific circumstances. According to FAR Part 15, cost-based purchasing is the "review and evaluation of the separate cost elements and profit" which comprise the manufacture of an item, and "the application of judgment to determine how well the proposed costs represent what the cost of the contract should be" (FAR Part 15.404-1 [c][1]).

A key strength of this method is that the collected cost information[1] strengthens the government's negotiating position. Price-based purchasing is the "process of examining and evaluating a proposed price without evaluating its separate cost elements and proposed profit" (FAR Part 15.404-1 [b][1]). It typically involves determination of whether adequate price competition exists. It makes a comparison of proposed prices to catalog prices, historical prices, prices paid by other commercial customers, prices derived from parametric estimates, prices from government cost estimates, and prices derived from any pricing information a contractor may provide (FAR Part 15.404-1 [b]). A key strength of this approach is that the process requires minimal expenditure of labor resources to execute a purchase. The hybrid-based purchasing method is an innovation of one service. It capitalizes on the strengths of the cost- and price-based approaches and will be discussed in greater detail in the research findings.

The data for this study were gathered through site visits to three different locations: two buying locations and the manufacturer. Two DoD sites support the replenishment of one of DoD's most plentiful, multiservice engines, with a Defense Logistics Agency (DLA) depot purchasing on

a cost basis and a service depot purchasing on a hybrid basis. Their performances are compared to the manufacturer's best commercial customer, where the commercial customer is buying on a price basis.[2]

Using $142 million in spare part purchases from samples spread over 5 years, both before and after the implementation of the DoD's price-based purchasing policy, the findings clearly show that cost- and hybrid-based purchasing have resulted in substantial savings for DoD. Across the samples of data, the results show that DoD paid $157 million less than would the manufacturer's best commercial customer buying on a price basis (DoD paid $142 rather than $299 million). If the DoD had purchased these engine parts at commercial catalog prices, as some believe the DoD should, the DoD would have had to pay an additional $285 million. On the surface, the cost-based approach appears to result in lower cost acquisitions than the hybrid-purchasing approach. However, the real picture may be more complex. Did the service's hybrid-based approach free up labor costs normally devoted to supporting cost-based purchasing? Did hybrid-based purchases deliver other benefits, such as better delivery terms? Did the cost-based approach, while getting DoD the best prices, create a more time- and labor-intensive buying approach? This article explores these issues in greater detail as well.

Background

During the past 7 years a spate of reforms in DoD has transformed many acquisition processes, using commercialization as the mantra for many of the changes. Ironically, in the name of "commercial practices," price-based purchasing is being pushed for buying noncompetitive items, even though purchasing on a cost basis is a common commercial practice in noncompetitive markets (Perrow, 1970; Pfeffer, 1978; Hardy and Magrath, 1987; Burt, 1989; Myer, 1989; Cross, 1995; and Taylor and Wiggins, 1997). This raises questions about the judiciousness of the blanket application of price-based purchasing policy in defense purchasing.

This research extends earlier work by Besselman, Arora, and Larkey (1999, 2000) and Besselman (1998) that predicted price-based purchasing of noncompetitive items would result in greater financial costs to the U.S. Armed Forces. That research provided considerable quantitative evidence that cost-based purchasing should be the method of choice when buying large quantities of high-value items in noncompetitive markets. To extend that work, a survey of engines was accomplished to identify where cost-based and other methods of purchasing are used to support a single system. It identified a multiservice engine that is sold and supported by one company. The DoD owns a set of engineering drawings, so it sometimes uses secondary sources of supply for a small number of the less complex parts within the engine. Although the manufacturer believes the engine is a commercial item, with more than 50 percent of its part sales to non-DoD customers, the engine's market

"On the surface, the cost-based approach appears to result in lower cost acquisitions than the hybrid-purchasing approach."

consists primarily of militaries of the United States and its allies, both past and present. In a classic economic sense, this engine's market, with one supplier, is not competitive.

The purchase of the spare parts to support this engine by the DoD is accomplished at two locations: a DLA depot and a service depot, although it is a multiservice engine. Until 1996, one service purchased all parts for this engine on a cost basis, both reparable and consumable parts. Since that time, the purchase of consumables was transitioned to a DLA depot. The DLA depot purchases the consumables on a cost-basis while the service depot transitioned the purchase of reparables to a hybrid-based approach. This split in the support of this singular engine made it possible to compare the purchasing methodologies fairly. The use of different methods by the two organizations makes it possible to compare the performance of these methods.

"The use of different methods by the two organizations makes it possible to compare the performance of these methods."

A brief discussion is required to distinguish reparable and consumable spare parts. Reparable spare parts for an engine are typically more complex and expensive on a per-unit basis. These are parts that can be repaired or machined and put back into service. The government typically rewards manufacturers with greater profit for the successful manufacture of more complex items. Complex, reparable engine parts are typically purchased in smaller quantities, thus sometimes negating the scale efficiencies associated with the manufacture of tens of thousands of consumables such as turbine blades. Within the service depot sample, reparable parts cost on average more than $5,000 per item. Consumable parts, on the other hand, are bought in large quantities to exploit scale efficiencies, are usually simpler to manufacture, and are typically thrown away or sold for scrap once they have been used. Within the depot samples, consumables cost on average approximately $60 per item.

Research Approach

We visited the two sites and gathered purchases from on-line databases and contract files. Both organizations were highly professional and cooperative, providing staff experts to help gather the information and answer contextual questions about the purchases. Both sets of the most recent data contained discrepancies that caused the removal of some purchases from the analysis.

The service depot purchases parts using a multiyear blanket purchase agreement (BPA) with the manufacturer.[3] The BPA has two tiers of discounts on the catalog prices: 41 percent for the first $20 million in purchases within a fiscal year and 56 percent for all volume above $20 million. According to the service depot's buyer, this was intended to collect $3 million from the DoD to cover field engineering support services provided by the manufacturer.[4] Therefore, to ensure an apples-to-apples comparison, $3 million to remove the financial effect of the engineering support from the comparison will adjust the service's aggregate result down.

Although the BPA established set discounts, some purchases had discounts greater and less than the prescribed amounts.[5]

The DLA depot had no such purchasing agreement with the manufacturer. It purchased all of its spares on a cost basis. Purchases by DLA were gathered in two samples from 1997–98 and 1998–99. Since DLA reports its purchases using both in-process and pending quantities, its data were carefully reviewed and only purchases that had been completed were included in the sample.

The analysis of the purchase data follows a very simple approach. Purchases were aggregated and compared to catalog prices and the price paid by the manufacturer's best commercial customer, where the best commercial customer was buying on a price basis. The percent differences between the aggregate cost for each depot were then compared. Another sample of purchases from the service depot in 1995, prior to the introduction of the price-based purchasing policy, is also incorporated into the analysis. At that time, the service depot was purchasing all spares for that engine, both reparables and consumables, using the cost-based purchasing method.

Research Results

For this engine, the results clearly show that buying noncompetitive items on a cost and a hybrid basis is vastly superior to price-based purchasing. The DLA data revealed that in 1997–98 and 1998–99, the DoD paid 70 and 68 percent, respectively, below catalog or commercial cost. The price difference is computed by subtracting the commercial cost from the DoD's cost and then dividing the remainder by the commercial cost. The service depot, however, buying on a hybrid basis, received an average discount of only 63 percent off the catalog price. A summary of these results is provided in Table 1.

The important finding, one the general public does not expect, is that the DoD, regardless of the purchasing approach, significantly outperformed this manufacturer's best commercial customer, where "commercial" in this sense means a third-party supplier that services primarily foreign governments and the few legitimate commercial users of the engine.[6] Looking across the samples spanning the past 5 years, the DoD paid $141.9 million for its spares while the manufacturer's best commercial customer, buying on a price basis, would have paid more than $299

Table 1. Summary Results of Engine Purchases[a]

	Number Buys	Gov. Cost ($)	Comm. Cost ($)	Gov.–Comm. % Difference	Best Comm. Customer ($)	Gov.–Best % Difference
1995 Service data	71 (cost)	59.3	176.0	–66	123.2	–52
1997–98 DLA data	88 (cost)	32.7	108.1	–70	75.7	–57
1999 Service data	84 (hybrid)	28.0	75.0	–63	52.5	–47
1998–99 DLA data	61 (cost)	21.9	68.0	–68	47.6	–54
Total	304	141.9	427.1	–67	299.0	–53

[a] Costs are in millions of dollars.

million, a savings to the DoD of more than $157 million.

What if the BPA did not exist and the service depot had to buy the parts on a purely cost basis (using the cost-based purchasing method)? Using DLA's most recent price difference, 68 percent below catalog prices, the service depot could have paid only $24.1 million rather than the $28 million paid, a *savings* of approximately $4 million. Conversely, had the DLA depot used the BPA and received only a 63 percent discount, the DLA depot would have paid the manufacturer $7.6 million and $3.5 million *more* in 1997–98 and 1998–99, respectively. The 1998–99 result will soon grow because DLA had approximately $20 million more in purchases in the pipeline when these data were being collected.

"In theory, cost-based purchasing offers a significant advantage."

All else being equal, the purchase of consumables should have been slightly more effective than reparable purchasing since they are simpler components bought in significantly larger volumes. Comparing the 1999 DLA and service data, consumable purchasing was 5 percent more efficient than reparable. Since the purchasing methods were not the same, this difference cannot be attributed solely to the type of item. In the next section we explore these contextual differences.

Discussion of Results

The findings show clearly that buying noncommercial items on a cost or hybrid basis results in lower costs than price-based purchasing buying at either commercial catalog prices or at the discount of the manufacturer's best "commercial" customer. In readiness terms, for this one engine, the DoD was able to keep, depending upon one's basis of comparison, $157 to $285 million. A transition to price-based purchasing at catalog prices, as some officials advocate for all DoD engines, would have adverse fiscal consequences on readiness.

A lingering issue is whether the DoD performed effectively using the hybrid method in relation to purely cost-based purchasing. The next section further explores their differences and results.

Purchasing Methods

In theory, cost-based purchasing offers a significant advantage. It allows a buyer with significant buying power in a market to be near the informational level of the seller. The buyer with market power demands and receives cost information. Armed with good cost information, the buyer can negotiate a price that holds down the seller's profit.

Discussions with government and industry personnel reveal that cost-based purchasing also has its disadvantages. It is typically time- and labor-intensive for the buyer. Indeed, interviews with buyers as part of this research reveal that time delays have increased after the Federal Acquisition Reform Act of 1996 (FARA), because many industrial suppliers are trying to have markedly noncommercial items declared commercial via a "commercial catalog." If an effort is truly commercial or a contractor is successful in persuading a buyer that it is commercial, then the government is prevented from

collecting cost data, no matter how expensive the item may be. These efforts by industry, some dubious,[7] delay negotiations while the government determines whether the item is truly commercial. Delaying negotiations can have adverse consequences on readiness, as operational units may have to wait on an item. Another labor-intensive feature is the typical on-site review of the contractor's data and manufacturing processes.

From an industry perspective, a disadvantageous feature is the requirement that the contractor certify "to the best of its knowledge and belief, the cost or pricing data were accurate, complete, and current" [FAR Part 15.403-4 (b)(2)]. It can be further time- and labor-intensive (expensive) for industry if the contractor is also required to convert its data to government-specified formats. These factors imply that the government carefully consider purchasing circumstances before imposing a purchasing method.

Price-based purchasing also offers several advantages:

- It can be accomplished very quickly (publish a requirement and solicit prices from vendors).
- It uses minimal labor resources.
- Competition, rather than negotiation, is used to control prices.

It may require market research and the collection of commercially available cost information, but its transaction costs are typically trivial compared to what it costs to collect and analyze cost information. In both the public and private sector, price-based purchasing is the typical purchase method when buying items competitively available and widely used in the commercial sector.[8]

The major disadvantage of price-based purchasing is that the buyer is at a significant informational disadvantage without real competition. In many markets, meaningful cost information, whether certified or not, is simply nonexistent. Classical economic theory requires lots of suppliers for true competition. As a practical matter, there should be at least a half dozen suppliers to select from (Bresnahan and Reiss, 1990, 1991). Once bids have been received or prices surveyed, contract award is accomplished with the most advantageous firm.

The process quickly breaks down, however, if there are only a couple of suppliers. Although economic theory suggests that a single customer facing more than one supplier can drive the price down to marginal cost, economic theory also points to the possibility of tacit collusion when the number of suppliers is small. Further, even if the buyer can drive the price, if there is uncertainty about the costs of the suppliers, economic theory suggests that the buyer can do better if he has cost information rather than simply relying upon prices (See Baron and Meyerson, 1982; Grossman and Hart, 1983). One or occasionally two suppliers and one customer is the typical circumstance for the DoD purchasing custom parts and equipment for weapon systems.[9]

"The major disadvantage of price-based purchasing is that the buyer is at a significant informational disadvantage without real competition."

The service depot used hybrid-based purchasing, an approach developed to exploit the advantages of cost- and price-based purchasing.[10] They selected a group of parts (reparables) from a manufacturer's commercial price list with the intent of putting in place a BPA for those parts. In this case, the BPA is nothing more than an agreement by one government agency with a manufacturer to purchase parts at either set prices below or at a uniform discount off of a manufacturer's commercial price list. The depot then invested a small amount in labor to analyze certified cost and pricing data they had previously collected for a sample of these same parts. That analysis determined an appropriate catalog discount equivalent to historical prices based on cost and pricing data. That analysis provided an anchor for negotiations. They now had sufficient knowledge to negotiate a fair discount on the manufacturer's catalog prices, one that pays a fair profit. In the future, they intend to collect cost and pricing data for a statistically valid sample of the parts to either revalidate the discount or negotiate a new discount.

"One could label the hybrid approach the 'trust but verify' theory of negotiation."

The buyers and engine managers believe the hybrid-buying approach engenders trust between the government and manufacturer by increasing "contracting velocity," the speed at which a buyer contracts for an item, while also giving the government the opportunity to verify. The trust arises through government and contractor teamwork, using minimal labor, with very little contractor disruption. Cost data is collected on a small, representative sample of parts rather than every single item the government may purchase out of a catalog. This saves the government and contractor time and labor. Verification occurs by basing the discount on cost data for a statistically representative sample of items in the contract or catalog. One could label the hybrid approach the "trust but verify" theory of negotiation. Once in effect, the BPA then delivers the strengths of price-based purchasing: quick, easy purchases with commercial delivery terms.

Labor

Using the most recent results, the service depot, using the hybrid method, was approximately 5 percent less efficient purchasing than the DLA depot. Are there intangibles in hybrid-based purchasing that make it the better option, despite the greater transaction cost involved? A major consideration should be the possible reduction in labor charges from not having to collect and analyze cost and pricing data, both for the manufacturer and DoD, and negotiate each individual contract. In this case, there could have been 84 separate contract actions had the service depot not established the BPA. In actuality, there have been no savings from not having to collect cost and pricing data for these purchases. First, the Defense Contract Audit Agency (DCAA) unit did not downsize as a result of the BPA. Second, the manufacturer already possesses a sophisticated activity-based cost accounting system that tracks costs rigorously, whether or not cost and pricing data are requested by DoD.

Not having to negotiate 84 separate contract actions certainly reduced labor

costs. But these cost savings are substantially less than the $4 million "loss" the service depot experienced by not using cost-based purchasing. A contracting officer and four buyers could have accomplished the 84 contractual actions. Assuming a generous labor cost of $200,000 per staff year, the total labor bill would only reach $1 million, far below the estimated $4 million "loss."

More Favorable Terms

Another consideration is whether DoD earned more favorable terms through the use of the BPA. The BPA's delivery terms and lead-time requirements are right out of the commercial catalog, so there is no additional benefit. Furthermore, if delivery requirements are shorter than the product's lead time, the service depot must pay the catalog price. Even when the DLA depot violated the manufacturer's lead-time requirement buying on a cost basis, they paid a price near or above the catalog price on only one occasion. In effect, the DLA depot buying on a cost basis enjoyed better delivery terms than the service depot.

Emergency Buys

One area of concern with the cost-based buying done by the DLA depot is the frequency of emergency buys. These are buys made in small quantities and typically at considerably higher prices to meet a near-term demand. This can occur because the depot was notified about the requirement either too late by the item manager or its buying process took too long because of some inefficiency. Although it looks bad for the DoD to pay $70 for a turbine blade that normally costs $19 because of poor planning or execution of the buy, the overall effect in this case is not severe since the quantities are so small. If the emergency buys were removed from the 1998–99 DLA depot sample, DLA purchasing would improve by only one-half of one percent. However, if that small percentage difference were applied to the dollar volume across several engines, this inefficiency could pose an adverse impact on readiness dollars. Therefore, the DLA and service buyers should endeavor to eliminate emergency buys.

The missing part of this analysis is whether there was an adverse readiness effect because a part was not in the field when it was needed. It takes time to buy on a cost basis. Were missions scratched because the buying processes were taking too long? In talking with the engine's manager, this indeed happens, although not nearly as often as it did back in the 1997–98 time frame. This is another hazard of not having pervasive organizational measures for the leadership to assess the costs and effectiveness of the buying. The warfighter needs to rigorously oversee this process to ensure purchases occur on time and mission execution is not adversely affected. This is the thread inextricably linking acquisition and readiness.

"It takes time to buy on a cost basis."

Lean Manufacturing

A near-term extension to this research will compare changes in real prices over time. At this manufacturer's facility, a significant manufacturing improvement program was undertaken throughout the early 1990s. The DoD underwrote a portion of

this modernization through the payment of higher prices with the promise that prices would begin to fall in the late 1990s. Although inflation has not been a factor in the markets supplying this manufacturer; on an anecdotal basis, prices have continued to rise. This is a concern considering the degree of innovation that has occurred on the manufacturing floor.

This manufacturer has aggressively pursued innovations commonly referred to as lean manufacturing. For example, a major manufacturing cost driver is the length of the manufacturing line. This engine's line has been reduced from more than two miles down to less than a half mile. In most normal commercial markets, particularly when items are manufactured over many years, there is a learning curve that continually drives down costs and consequently prices. At this site, the DoD has not reaped any of these savings. This is something the DLA and service depot should examine on an amicable fact-finding basis. The intent should be to understand why the manufacturer has not returned any savings, rather than to put profit pressure on the manufacturer, adversely affecting its financial health.

"...price-based purchasing should be the method of choice for most of what the DoD buys: commercial items bought in competitive markets."

CONCLUSIONS

This research is neither an indictment of price-based purchasing nor a confirmation that the DoD should revert back to cost-based purchasing for all or most of its buying. On the contrary, price-based purchasing should be the method of choice for most of what the DoD buys: commercial items bought in competitive markets. But like large commercial firms with significant market buying power, DoD should exploit cost-based purchasing or the hybrid method when acquiring noncommercial items of significant dollar value in noncompetitive markets. This modest tweaking of the current policy would put the DoD more in line with commercial buying practices.

The service depot and other organizations should continue to refine the hybrid method. Although the hybrid method was slightly more inefficient (5 percent) from a cost perspective, the service depot believes that was more than overcome by awarding contracts quickly and easily, for both the government and manufacturer. In reality, considering the service depot was buying more complex components in smaller quantities, we expected their performance to suffer slightly, perhaps by a few percentage points. Nevertheless, the service depot should collect cost and pricing data for a statistically representative sample of the parts they seek to put on contract. The depot should follow this up by spot checks to minimize the presence of expensive outliers.

The DLA depot should carefully consider these findings and the benefits they perceive from purely cost-based buying. The service depot has demonstrated that it can get within 5 percent of DLA's performance using the much simpler and more timely hybrid approach. The service depot could easily extend the BPA to account for all parts supporting this engine

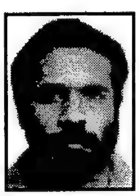
and free up valuable DLA labor resources. A single BPA for all parts for both DoD organizations would be a win-win formula for government and the manufacturer.

Other part managers, particularly managers of noncommercial items or systems, should take a hard look at the hybrid approach. If one collects cost data on statistically valid samples, one should be able to arrive at discounts for subsets or entire catalogs that rival discounts received by using cost-based purchasing uniformly. This approach should free up valuable depot, DLA, and Defense Contract Audit Agency labor resources and significantly increase the velocity of our purchasing.

This research highlights the most pervasive commercial practice that continues to elude the DoD: rigorous and widespread organizational measurement. In the DoD, organizational measurement within and across much of what is called defense purchasing is not presently required. An organizational measurement initiative comparing the military services, buying sites, internal organizations, and weapon system offices would enable the leadership to more effectively guide defense procurement toward genuine process improvement. This research's simple organizational measurement exercise showed that a $157 to $285 million adverse impact on readiness could have occurred if the buyers in the field had simplistically implemented a price-based purchasing policy. Readiness, in general, however, will continue to suffer from inefficient purchasing until the leadership embraces coherent and pervasive measurement across its logistics and acquisition enterprise.

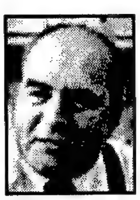
Maj Joe Besselman, U.S. Air Force, is presently an action officer with Installations and Logistics, Headquarters of the U.S. Air Force in Washington, DC. He has served in a variety of weapon and combat support system software program management positions. He is a graduate of Th Defense System Management College's APMC 99-3 class. He has a Ph.D. degree in public policy analysis and management from Carnegie Mellon University and an M.S. degree in electrical and computer engineering from Louisiana State University.

(E-mail address: joe.besselman@pentagon.af.mil)



Ashish Arora is associate professor of economics and public policy at Carnegie Mellon University, Pittsburgh. Professor Arora's research focuses on the economics of technological change, the management of technology, intellectual property rights, and technology licensing. He has in the past worked on questions of the productivity of university research, and the growth and development of biotechnology and the chemical industry. He has a Ph.D. degree in economics from Stanford University.

(E-mail address: ashish@andrew.cmu.edu)



Patrick Larkey is a professor of decision making and public policy at Carnegie Mellon University. His administrative assignments have included head of the Department of Social and Decision Sciences, associate dean for academic affairs at the H. J. Heinz School of Public Policy and Management, and chair of the faculty senate. He earned a B.A. degree at Stanford University and M.P.P. and Ph.D. degrees at the University of Michigan. He is the author of numerous books and articles. His current research centers on the foundations of performance measurement.

(E-mail address: pl15@cyrus.andrew.cmu.edu)

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ENDNOTES

1. Cost information is little more than a decomposition of the unit price, revealing the various constituents such as materials, labor, anticipated profit, and possibly the cost of money. It can be highly variable and the government, unlike the commercial sector, may require a contractor to certify the information, which can introduce legal consequences should the vendor misrepresent its costs. While some large commercial companies may require certified cost data, the only potential penalty from misrepresentation is that the buyer may take his or her future business elsewhere.

2. These sites as well as the specific engine will not be identified. A precondition for gaining access to some of this data was that the manufacturer would not be identified so that their proprietary information, the discount their best commercial customer pays, would not be publicly revealed, particularly to their other customers. Confidentiality is a common feature in DoD acquisition research and can be found in seminal works by such distinguished researchers as Peck and Scherer (1962) and Gansler (1978, 1982).

3. A BPA is not a contract; rather, it is more of a charge account with qualified source(s) of supply to fill.

4. The field engineering support for $3 million was provided to the field in anticipation of problems. Adding 15 percent to the first $20 million in spare part purchases was viewed as an efficient means of collecting the money and paying for services that were typically difficult and time consuming to contract for. No longer did the item manager have to contract individually when a crisis or problem developed in the field. He could now immediately deploy contractor resources to fix problems. In effect, contracting velocity (speed at which a contract is put in force) is significantly increased and customer wait time lowered. This is similar to contracts used by some airlines. Besselman (1998) identified one major commercial airline that buys parts and services for at least one engine in this manner.

5. Although the item manager, buyer, and contracting officer could not explain this discrepancy, it does not materially change the final results.

6. In the aggregate, the DoD is the largest buyer, but the majority of part sales go to non-DoD buyers. The volume of purchasing by the largest commercial customer is comparable to one of the DoD's individual depots.

7. Some contractors will go to great lengths to have an item declared commercial. During a fall 1999 visit to a depot, one reputable firm was attempting to use sales of military parts to mercenaries on the African continent as evidence of "commercial sales."

8. One of today's widely held urban legends is that there is one way the commercial sector does something. Purchasing is no exception. We have seen suppliers to a large retailer and fast food chain provide cost visibility into such commercial items as baby clothing and ground beef and other ingredients, respectively.

9. Monopsony, the case of only one customer, is analogous to monopoly. Thus, in a monopsony, the buyer can usually do better by gathering information about the cost of production, but only by introducing inefficiencies (e.g., see Blair and Harrison, 1993). We suggest using price-based purchasing even when DoD is the only customer as long as many firms supply the item under competitive conditions.

10. This technique is nearly identical to an approach DLA pioneered with Honeywell and showcased at the 2000 Acquisition and Logistics Reform Week, Washington, DC, May 22–26, 2000.

    Transaction costs are typically costs of contracting with third parties (e.g., see Williamson, 1985). In this case, these costs include the cost of collecting and analyzing cost data and negotiating contracts.

BUILDING A BUSINESS CASE FOR MODELING AND SIMULATION

C. David Brown, Ph.D., COL Gordon Grant, Canadian Forces, LTC Donald Kotchman, USA, COL Robert Reyenga, USA, and Lt Col Terence Szanto, USAF

Modeling and simulation technology is the use of models to develop data as a basis for making managerial or technical decisions. It can be a valuable tool for program managers—but it is one that is vastly under-used. This article provides a business-case framework (a methodology to evaluate investment opportunities) for program managers within the Department of Defense to use when determining how to apply modeling and simulation in project management.

The use of modeling and simulation (M&S) is widely misunderstood within the Department of Defense (DoD). M&S is the use of models, either statically or over time, to develop data as a basis for making managerial or technical decisions (DoD, 1997). Models are physical, mathematical, or logical representations of a system, entity, phenomenon, or process. Simulations are methods for implementing models over time. Normally, we associate simulations with a software program that implements models over time, within the context of a given scenario (Defense Modeling and Simulation Office, 1996). Simulations permit the user to assess variables and the predictability of a single or series of outcomes.

Nowhere is the misunderstanding more painfully obvious than within the program management offices of the DoD. Some program managers believe M&S is paramount to effective project development and place the requisite investment in it (and this article highlights examples of some such programs). But many program managers remain both skeptical and suspicious. Recent government direction to use simulation-based acquisition in DoD programs is an example of a policy with good intentions but poorly shaped execution. This edict has been met with, at best, marginal acceptance, and at worst, abject resentment.

Such resentment and apprehension spring from institutionalized biases,

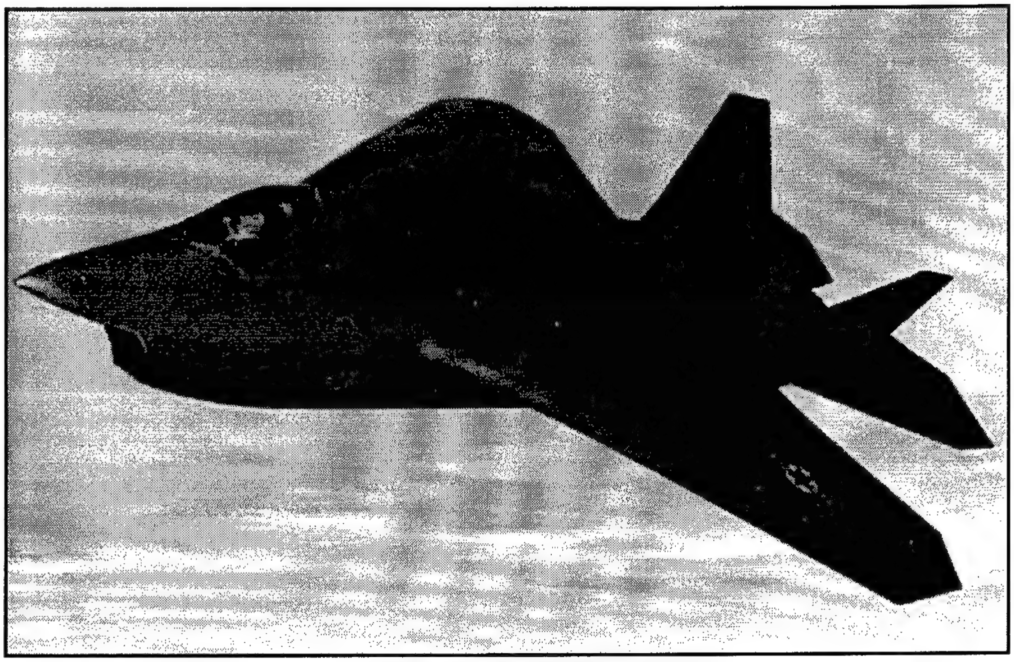
including DoD funding procedures, that work against optimizing the potential gains of employing modeling and simulation. By far, the severest criticisms targeted at M&S center on the debate over return on investment (ROI). As we will discuss later, ROI is just one of many techniques in evaluating the use of M&S in a program. Ostensibly, DoD has accepted this new technology as a means of reducing costs, increasing cost avoidance, and banking the residual benefits for other projects.

Many program managers argue that the entire acquisition system is focused on getting a project into production, through performance trials, and permanently into the military's inventories. Seldom are they given sufficient funds, staff, or time to investigate the potential benefits of tools or technologies such as M&S. Importantly, leadership provides little incentive to capture data, build expensive models, or conduct additional analyses to transfer M&S results to other projects. Simply put, program managers are under intense pressure to complete their programs on or under budget and within timelines. Existing programs lack enticement to develop new models or simulation tools that may have wider application to other programs, or that will be much cheaper to operate and sustain. With few exceptions, these occurrences were more a result of coincidence than deliberateness.

"Simply put, program managers are under intense pressure to complete their programs on or under budget and within timelines."

Finally, perhaps the greatest impediment to M&S acceptance is lack of knowledge. Many people do not understand the potential benefits of this technology, or how to define needs and produce the right tools that will help the project. Unfortunately, this reticence may be reinforced by an institution which neither favors nor rewards risk takers. Sometimes, a program manager may not know for certain if a major investment in M&S is warranted. If a program manager wants to invest in the technology "just to see if there is a benefit," he or she faces criticism if the results are not positive. Thus, a program manager must weigh the costs of the risk, and consequently few take the chance, preferring more traditional approaches—the building of expensive mock ups; the use of labor-, time-, and money-intensive trials, and incurred costs of waste.

The deputy project manager (DPM) of the Joint Strike Fighter (JSF) praised the future of M&S while lamenting the military's reticence to embrace it. "The Joint Strike Fighter Project achieved immeasurable benefits from its innovative use of modeling and simulation. More important, I was impressed with the tremendous intellect and drive of many of the staff who were willing to try new models. They did simulation runs—sometimes up to 1,000, in order to bring this project along a development path to bring the necessary technology-enhanced fighter into the 21st century. They took the risks and it's paying off" (1999).[1] The DPM made this blunt statement—"No high-tech project will achieve any significant success if it does not incorporate M&S. However, we in DoD just aren't ready to capitalize on this technology."



Joint Strike Fighter

While all of this bodes well for an anecdotal argument supporting M&S, what's needed is a more reasoned and defensible process for determining M&S investments. While few refute the intuitive benefits of M&S, program managers quite rightly argue that any tool must be first measured against its potential benefits before it is used. For example, given that Boeing spent $2 billion on M&S for its 777 airplane, are comparable levels of investment affordable to program managers of programs of similar magnitude? Obviously, the question is not easily answered. It depends on a variety of factors, including the project's funding, period to recoup the investment, and perceived benefits to developing and using M&S in the program. The crux of the problem is the dilemma of costs versus risks and the potential return. Program managers need a methodology to evaluate investment opportunities.

Methodology and Approach

The authors reviewed selected M&S efforts within civilian industry and DoD. We visited several key manufacturing and service industries, which were also wrestling with the same subject—the assessment of M&S investment. Understandably, each sector had a slightly different motivation or incentive to invest in M&S. One company was concerned about long-term applicability and the transference of technology to future programs. Another was in the business of capturing data and shaping models and the requisite simulation runs to satisfy client needs. They were using training models and virtual reality

technology as a means to reduce training costs and time. Another believes a judicious application of M&S reduces direct manufacturing costs. For example, on the JSF program, simulations are improving mechanical tolerances such that developers project shim stock weight reduction from an average of 40 pounds per aircraft (as is the case with the F–16) down to less than 1 pound. Such projections are reasonable, based on actual data from Boeing 777 design and projection.

While there are some common applications industry-wide, DoD is not focused on profit, but on performance and total ownership costs.[2] We surveyed a large number of DoD program managers, with programs in various stages of the acquisition process. The survey requested general information from the program managers regarding how they made decisions on M&S investments. Additionally, in an effort to maintain balance, we also surveyed several government contractors. We also conducted a literary search to capture the body of knowledge in non-government organizations related to justifying M&S investments.

Results of Surveys

In general, survey responses indicated that program managers are investing in M&S to support program development; however, most of the investment decisions were based on intuition or need-based factors. Most decisions were made without detailed quantitative analysis. Ostensibly, program managers accepted modest investment in M&S because they believed that it would benefit the program. These efforts, however commendable, lacked a methodical cost-benefit analysis. Additionally, the lack of a structured business case analysis made it difficult, if not impossible, for program managers to articulate or substantiate their investment strategy. In some cases it came down to a program manager wishing to explore M&S

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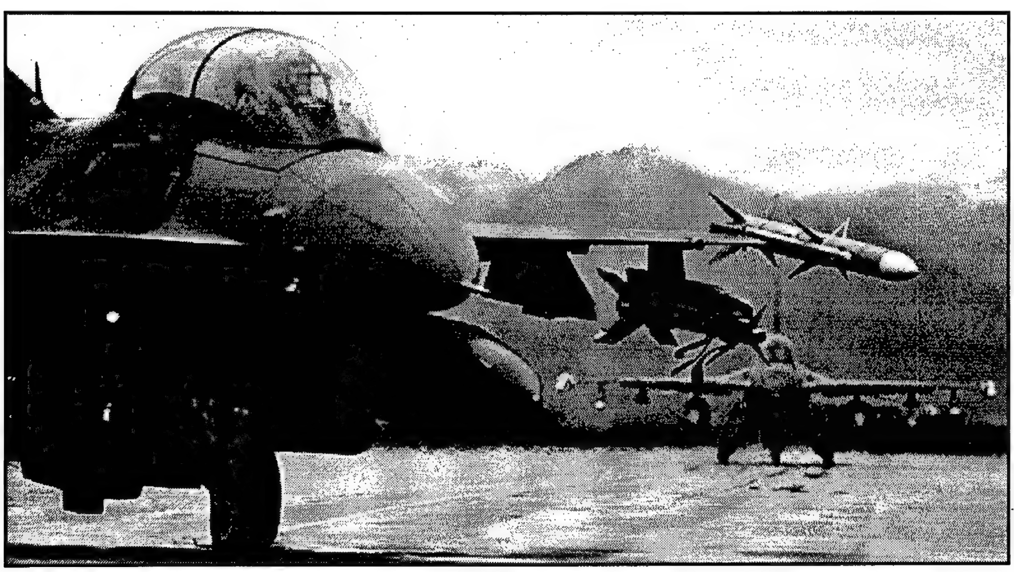

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without knowing what benefits might be achieved. This is not really taking a risk; it is more an exploratory probe into a new field. These program managers were embracing new technology—but without a sound business case approach, they could not really assess if the investment would realize considerable benefits or generate prohibitive costs.

Most program managers justified their M&S investment based on one or more of the following:

- reducing design cycle time;
- augmenting or replacing physical tests;
- helping resolve limitations of funds, assets or schedules; or
- providing insight into issues that were impossible or impracticable to examine in other ways.

Much of the feedback reflected that program managers had tried to examine costs and measure them against benefits—but without the help of any business case analysis format. Consequently, approaches and results varied. Few reported to have used a disciplined approach. The use of inconsistent applications or approaches leads to mixed results that cannot be readily compared or evaluated. The majority of respondents suggested the question of using M&S was not one of "Should I" but rather, "How can I?" This demonstrates general acceptance that M&S is required in an efficiently managed program. But it begs the question "at what cost?" Indeed, the cost of investment may be prohibitively expensive, or there may be only the most marginal long-term benefits to the department. In such cases, the decision maker should select from alternatives, be it foregoing M&S, partnership with other program managers to share costs, or leveraging the investment of others. This is not a moot point, given DoD's fiscal limitations.

Program managers want confirmation that investment in M&S will yield direct savings within their budgets. Considering that much of the benefit of M&S investment is intangible, traditional measurement approaches may not provide an accurate assessment. Additionally, program managers may be understandably too parochial in that, if the return is not significant for their immediate project needs, they may dismiss these tools. But projects are relatively short-lived—we may very well be missing some of the longer-term residual benefits. While traditionally the benefits of M&S tend to be discussed in terms of return on investment, several alternatives for business case analysis can just as effectively justify M&S investments. The challenge is to define an appropriate strategy and priorities to address the business value proposition.

"Program managers want confirmation that investment in M&S will yield direct savings within their budgets."

A disciplined approach and methodology has many benefits. It can help bring the aggregate benefits into focus and strengthen the argument for M&S investment. A business case analysis provides a convenient mechanism for project management. It can be an easy-to-follow, logical thread. It also lays the groundwork for

others to attain information that will help their respective programs. This approach forces a timeline, captures benefits, and enables authorities to decide if the return is worth the pursuit.

MAKING THE BUSINESS CASE

Corporate America is taking a methodical approach to investment decisions regarding M&S. Although they are primarily profit driven, they share common maxims of production—such as cost reduction, efficiency, and cost avoidance—to that of DoD. Essentially, a business case will assist the program manager in evaluating which of a number of logical packages of alternatives will best meet the program's objective.

EXISTING GUIDELINES AND INSTRUCTIONS

The survey revealed that although DoD has issued guidance on this subject, few program managers reported that they were following it. DoD guidance on investment guidance is provided by DoD Instruction (DoDI) Number 7041.3, *Economic Analysis for Decisionmaking,* (1995). Enclosure 3 of the DoDI, *Procedures for Economic Analysis*, provides an insightful overview of methodology, criteria and a discussion of sensitivity analysis (1995). The General Services Administration's *Information Technology Capital Planning and Investment Guide*, (1998), also provides procedures for economic analysis. Some services may also have supplemental guidance (U.S. Army cost and Economic Analysis Center, 1995).

"The baseline provides a benchmark from which decisions will be weighed and assessed."

A BUSINESS CASE FRAMEWORK

Given our research, the results of surveys, discussions with industry and our literature search, we recommend a seven-step process for assessing the utility of M&S investments:

- Establish a baseline.
- Establish a vision and direction.
- Quantify the costs and benefits of alternatives/capabilities.
- Evaluate alternatives.
- Conduct sensitivity analysis.
- Develop a migration strategy.
- Monitor the process and continue to assess results through formalized feedback.

STEP 1. ESTABLISHING A BASELINE

As with many other decision-making processes, the first step is to establish an accurate baseline. The baseline provides a benchmark from which decisions will be weighed and assessed. The baseline should include a clear enunciation of assumptions and constraints. Assumptions are explicit statements describing the present and future environment. They reduce complex situations into manageable proportions. These assumptions normally

provide some comment on the estimated future workload, the useful life of the investment or system, and the period of time over which alternatives will be compared. Assumptions should also discuss sunk costs and realized benefits, but are not included as part of the baseline. Constraints are those factors that limit alternatives. Normally they are expressed in terms of time, finances, institutional or regulatory statutes, or directives and physical plant and assets.

The baseline must identify the "higher-value" portions of a program in order to evaluate the appropriateness of various alternatives. For example, in the case of an aircraft, 75 percent of program hours might be expended on the air vehicle team. On closer examination, one might find that 45 percent of that time goes into airframe design, and of that figure, 90 percent is expended on mid-fuselage development. With this informed examination, the program manager will be better able to allocate M&S spending where it will offer the greatest potential savings or benefits. The baseline must determine these high value areas for effective business case analysis. These program specifics form the drivers to the program, which in turn drive the investment process.

Step 2. Establishing Vision and Direction

One must look to the future, then bridge the gap between present knowledge and that required to make future products a reality. A program manager must establish the program's vision. As with other technologies, the program manager's vision should consider how M&S tools can improve program costs, scheduling, and performance, and whether scientific knowledge exists to support such M&S investment. The vision should drive what the M&S tools should be trying to solve, not the other way around.

For example, although the Big Three auto companies in Detroit are producing very similar products, each is using M&S in very different ways, based upon their strategic visions. One is concentrating heavily on using M&S in design at a single location; another is concentrating on moving large amounts of digital information around the world in order to develop a global engineering capability; and the third is heavily investing in reducing the costs of manufacturing. Of course each is doing some or all of these, but the vision provides the focus for allocating their scarce resources. It clearly identifies *what* is to be achieved, without dictating *how* it will be done.

"A program manager must establish the program's vision."

Step 3. Quantify the Costs and Benefits of Alternatives and Capabilities

Alternatives are logical packages of initiatives that work well together (Kidwell, 1998). One alternative is the status quo—that is, what we identified as the baseline in Step 1. In some cases the baseline, often a physical test, can be more cost effective than the use of M&S. Other alternatives should represent various combinations of M&S tools that help achieve the vision. In determining alternatives, one must consider both immediate and long-term effects. First, what is it the program needs to perform better? Second, what does the program need in order to survive until the next stage? Most certainly, a

program must satisfy a requirement, but it must also endure and survive each step of the process. It does no good for a program to bankrupt itself with massive unfocused M&S investment early on. Each investment must produce value during a time-frame that is appropriate for the program. Reality requires meeting near-term milestones. The alternatives must also consider the technological advances in M&S tools that might occur. A program might not be justified in spending huge sums of money on M&S technology that will be superceded and rendered obsolete in 2–5 years.

The program manager must identify all costs that are incident to achieving each alternative. Models and simulations can be expensive to develop, particularly in domains where the scientific principles are not fully understood as applied to the problem. While additional research can fill the knowledge voids, the cost of this research must be factored into the analysis of alternatives. These should include the opportunity costs of assets and resources, which are the alternative value foregone when an asset is used for other purposes (DoDI, 1995). They also include nonrecurring and recurring costs. Life-cycle costs should include all costs, nonrecurring and recurring, that occur over the life of an alternative (General Services Administration, 1998).

"Identifying alternatives may be the most difficult portion of the process."

Identifying alternatives may be the most difficult portion of the process. Benefits must be viewed primarily in terms of measurable value. Expected benefits should flow from the clear operating vision developed in Step 2. Enigmatically, there are both quantifiable and unquantifiable benefits. The former have some tangible or readily identified returns; the latter have less so. Additionally, there may be benefits that have no intrinsic value to one program but provide value to others. We call these external benefits.

Quantifiable benefits. These include cost savings, time improvement, acceleration of deliverables, quality enhancement and, in most cases, cost avoidance that is directly related to the program. The alternatives must also consider existing systems and programs. If we are to measure improvements from an "as-is baseline"—we need not start from ground zero. It may be possible for program managers to look at M&S initiatives in other programs, assess their applicability, and leverage them for success. Cost associated with these alternatives should be less, given that a majority of the investment would be a sunk cost borne by others. Similarly, program managers must consider whether partnering with another program, thereby sharing costs, is a possible alternative to reduce up-front investment. Program managers should ensure they have examined all potential benefits by using published references and experts in the field of cost analysis.

Unquantifiable benefits. Traditionally, we have considered the issues of risk reduction, organizational efficiency, technology transference, product safety, and environmental impact reductions as unmeasurable and therefore unquantifiable. However, these are important issues, and program managers must consider them in their analysis. To illustrate this point, we will address technology transference.

The Grizzly

M&S technology transference can significantly influence costs, but in today's DoD environment it has yet to receive adequate attention. Given the shrinking public purse and the demand for greater accountability and responsibility for the dispersal of funds, all program managers must show due diligence in their public spending. They must consider the residual benefits of technology transference.

Some M&S investment might be of use to other projects and program managers. For example, the Grizzly[3] program manager invested heavily in chassis M&S to support short-term design and performance analysis. This M&S investment resulted in $21 million worth of quantifiable benefits to the Grizzly program. The Grizzly program manager funded the M&S effort through internal reallocation of funds. The program manager's supervisor, program manager Combat Mobility Systems, recognized the potential for the use of these models for both other program requirements and in other programs sharing the Grizzly's chassis. Program manager Combat Mobility Systems leveraged the Grizzly Program's M&S investment, securing funding to expand the applicability of the initial investment into other programs and to support other long-term Grizzly requirements.

When forecasting near-term savings in design and production costs, one of our surveyed companies accrued substantial unquantifiable benefits. The engineers made a substantial leap in M&S knowledge when learning how to define data needs, how to shape models, and how to refine simulation runs, to narrow the bandwidth of problem solving. The resulting expertise, data, and process could be applied to future projects. Not surprisingly, the company's models and data bank are

the envy of the industry. This was an unquantifiable gain. Another unquantifiable—or at least indiscrete—benefit of M&S is the competitive advantage it provides. This relates back to establishing a clear vision so that early investments will lead the company to where it wants to be in the future.

Unfortunately, many program managers dismiss the concept of unquantifiable benefits. program managers rarely track these benefits, or those outside the program's realm with any real vigor. They don't afford them reasonable weight when analyzing costs and their alternatives. Similarly, external benefits may exist, not only to service DoD at large, but to external agencies and businesses.

External benefits. These are benefits which do not bring direct return or savings to the unique program being managed, but have applicability beyond the program manager's purse. As mentioned previously, many M&S initiatives and their products can either be modified or directly transferred to other programs. Again, looking at the Grizzly program, the contractor supporting the program manager (United Defense Limited Partnership) developed a common product model database that benefited efforts at Aberdeen Proving Ground, The Army Warfighting Analysis and Integration Center, Waterways Experiment Station and National Training Center projects. Thus there is a residual savings for follow-on users. The surveyed program managers did identify a problem with the high cost of collecting data and maintaining the database. While the cost of performing this might be high, or perhaps even prohibitive to one project, it could be cost effective to several other end users. We must overcome the institutional bias that forces program managers to ignore external benefits. A program manager has no incentive to take on an M&S investment unless he or she can justify the expense from the existing (and often cash-strapped) program. The following example demonstrates how external benefits can show marked savings to DoD and the public.

"We must overcome the institutional bias that forces program managers to ignore external benefits."

For years the Aberdeen Test Center (ATC) put vehicles through multiple runs over ground to determine wear and tear on parts and the resultant performance degradation. This required a large number of personnel, vehicles and time to log thousands of miles to achieve statistically significant results. Since then, the ATC completed an intensive project where data was collected describing the complete profile of the course. Subsequently, engineers built the models and now conduct or augment many of these tests on a virtual proving ground using simulations in lieu of hardware. The simulations are so accurate that they have been able to document millions of dollars in cost avoidance for testing of Army programs, while concomitantly helping the Army make the requisite decisions for product and performance improvements. Not surprisingly, others outside the DoD, including private industry, insurance corporations, and the Department of Transportation, also want to use this product. (According to DoDI 7041.3, societal costs and benefits outside the federal government are usually not included in a DoD analysis).

Although this program has universal application, ATC had to offset the costs of this M&S project through internal savings in manpower and overhead, rather than being permitted to share the cost with other programs. An alternative strategy would be to identify potential users in advance and share the developmental costs. Undeniably, program managers should take the first step to accrue direct benefits to their programs. But they continue to bypass transferable benefits simply because direct program constraints preclude further investment of resources.

Perhaps the real value of identifying quantifiable and unquantifiable benefits is in helping others outside the program to realize potential synergies of reuse. For example, the program executive officer, who is charged with program oversight, will have better visibility into requirements and the potential benefits. He or she can more accurately assess M&S investment in relation to a broader sphere of programs. Operational analysis and training are just a few examples. Many of these benefits, while external to an individual program manager, may be internal benefit from the program executive officer's perspective. Armed with this information, a program executive officer may choose to redirect funding from other sources into the program, and/or direct a program manager to take a course of action which may not be cost-effective in a micro perspective; but will bring an aggregate gain that far outweighs the individual investment. But sound management is predicated on program managers providing the program executive officer with data and information drawn from the program manager's business case analysis.

Step 4. Evaluate Alternatives

We must compare the costs and benefits of each alternative and rank them. Such comparisons must be accomplished using both quantitative and qualitative techniques and criteria. Quantitative techniques include net present value, benefit cost ratio, return on investment, payback method, internal rate of return, hurdle rate, and cost effectiveness analysis.[4] Qualitative evaluation considerations such as relationship to business strategy, schedule risk, organizational and technical risks, social benefits, and legal and regulatory requirements may greatly alter the quantitative ranking.

"Undeniably, program managers should take the first step to accrue direct benefits to their programs."

The choice of appropriate tools is program and situation dependent, and can greatly influence the outcome of the analysis. These tools will aid decision makers in accurately evaluating all alternatives such that all costs and benefits are viewed on a level playing field. In general, each feasible alternative, life-cycle costs and benefits, are adjusted using discount factors to account for the time value of money. A complete analysis properly relates quantitative and qualitative factors. Given the importance of these choices, one should seek expert advice and guidance before proceeding.

Step 5. Conduct Sensitivity Analysis

Sensitivity analysis is an essential step in the decision process, as it accounts for ever-present uncertainties. Such analysis repeats the above evaluation of alternatives with changes to the uncertain variables

and examines the effect on the final decision. The outcome will provide a better understanding of the robustness of the output.

Sensitivity analysis is highly recommended, even if there appear to be significant differences among the alternatives, because an apparently superior solution may be very sensitive to changes in a single variable. Sensitivity analysis is required when differences among alternatives are less obvious and may be totally driven by variability of key input factors. The key factors to be tested may include, but are not limited to, project or program length, volume or quantity and mix of production units, requirements, configurations, assumptions, and discount rates and other economic factors.

"Program managers face tremendous pressure to bring a product into use."

Step 6. Developing a Migration Strategy

After determining the best alternative, one must develop a sound implementation plan to migrate the "winning strategy" into the program. This plan must incorporate a systematic approach whereby the developer plans to implement the identified drivers and capture the expected benefits. Implementation of the migration strategy will undoubtedly force changes to the program's plan and budget. If a new tool or process is expected to save money, then those savings should be subtracted from that part of the program budget and reassigned elsewhere as an up-front action.

Step 7. Monitoring and Assessment through Formalized Feedback

The final step in developing a business case will be to create metrics to assess progress toward the overall vision. These metrics should be tied to the changes made to the program's acquisition plan, to provide timely feedback on their success in meeting desired results in performance, schedule, and cost. Performance metrics should stem from the needs and requirements that alternatives are fulfilling, and should address the benefits they are expected to provide. Schedule and cost metrics must also be developed to help ensure programs adhere to planned costs and schedules (Kidwell, 1998; DoD, 1995; GSA, 1998).

Program managers face tremendous pressure to bring a product into use. While it is the program manager who can best provide monitoring input, funding limits and timelines debilitate an aggregate approach to monitoring. Unquestionably, program managers should consider the entire life cycle of the project. But in the present acquisition environment there is little incentive to do this. Program managers are the lynchpin to success, since they hold all of the program-specific information.

Program managers must deliver their programs with complementary benefits first. This is their true priority, but they should also identify real or potential external benefits up the management chain to the program executive officer. That office can then make more informed decisions on the macro benefits. Program managers should consider increasing investment earlier in the program if the business case strongly indicates downstream

savings as a result. Program executive officers can provide the attendant oversight and direction, with a requisite reallocation of funds when it is in DoD's best interest to do so. DoD has made some marginal progress, as historically, program managers did not worry about maintainability and sustainability issues. Now Gansler's revolution in military affairs is mandated through specifications and expectations in our contracts. Acquisition decision makers must shift expectations as M&S technology enables more informed tradeoff decisions against such things as disposal costs. We must include this approach in our business case analysis. This requires a fundamental attitudinal change not only on the part of program managers, but also for the entire acquisition team and DoD.

Monitoring needs to be a truly integrated process, with all elements actively involved. A sharing of analysis, combined with a DoD commitment to maximize and optimize any potential benefits of M&S technology, will bring unprecedented reward—in cheaper, better, stronger products and the associated prudence in managing the public purse.

Conclusions

Often, finding the solution to complex technological problems is a game of chance, where there are a limited number of variables but a near limitless combination of these to bring about technological breakthroughs. M&S permits the program manager to experiment with a larger number of possibilities without undue risk. Once the essential data is determined, collected, and then shaped within a model, the simulations provide a tremendous advantage over traditional methods of trial and error.

The use of M&S in program management is no longer reserved for programs on the cutting edge of technological development, nor is it simply an "experimental tool." Both industry and the government should rely on sound business practices for success. Both should also realize that M&S is an established business tool, and that M&S investment justification should be based on a reasoned cost-benefit analysis.

Unfortunately establishing the cost-benefit relationship of M&S investments can be just as daunting as the management of a program itself. The use of a business case development process to justify M&S development provides a flexible yet structured methodology for program managers to weigh alternatives. Business case analysis permits the program manager to justify investment decisions based on traditional discounted cash flow analyses, as a function of externally imposed constraints, and risk reduction. It allows program managers to capture not only those costs and benefits that are internally quantifiable and unquantifiable, but to address potential benefits that may exist external to the program. A disciplined approach to making investment decisions also provides a mechanism for those

"The use of M&S in program management is no longer reserved for programs on the cutting edge of technological development, nor is it simply an 'experimental tool.'"

outside the program management office to examine and assess investments for broader applicability.

Our research indicates that in a large section of the acquisition community, insufficient rigor is applied to M&S investment justification. We uncovered a variety of tools and references available to program managers for conducting business case analyses. Building a business case not only helps program managers ensure M&S investment is warranted, but serves as a reference for others when trying to make similar investments or as a baseline document that other program managers and offices can use when building investment strategies. Business case analyses also build strong justifications to defend M&S investments and bring rigor and discipline to the program or project management processes. The seven-step procedure identified in the body of this article captures the essence of available guidance, knowledge, and experience and should provide program managers with a starting point when considering M&S investments.

RECOMMENDATIONS

Having a clear understanding of the state of development we believe the following recommendations will serve to assist program managers with the development of modeling and simulation investment strategies based on a sound business case development processes.

- Program managers need to be encouraged to add discipline and structure to their M&S justification process. Service leadership must challenge program managers to use business case development methodology to support M&S investment decisions.

- Program managers require ready access to policy and guidelines from the General Services Administration, the Office of the Secretary of Defense, and each service in order to develop successfully a business case justification. We recommend incorporation of documents referenced in this paper into the *Defense Acquisition Deskbook* along with a section to serve as a primer for business case development.

- Program managers and their staff need adequate training in order to properly implement business case-based M&S investment strategy justification. Acquisition curriculum at service schools and the Defense Systems Management College should include business case development familiarization classes.

- Service leadership should capture success stories and publish them in appropriate service and DoD journals, magazines, other publications, and related acquisition Internet sites.

Dr. C. David Brown is a member of the Senior Executive Service and presently serves as the Director for Test and Technology for the Army Developmental Test Command, and previously served as the focal point for the Army's application of modeling and simulation techniques to technical test and evaluation. In addition to holding two patents, he has authored numerous technical papers, is a registered professional engineer, a member of the Army Acquisition Corps and is an Army Reserve Colonel assigned to the Army Chief of Staff. He has a doctorate degree in electrical engineering from the University of Delaware, and is also a graduate of the Industrial College of the Armed Forces.

(E-mail address: brownd@dtc.army.mil)

COL Gordon Grant is in the Canadian Forces.

LTC(P) Donald P. Kotchman, USA, serves on the program management staff for the Interim Armored Vehicle program as the systems risk manager and Mobile Gun System manager, and is scheduled to assume duties as the Project Manager for the Bradley Fighting Vehicle Systems in 2001. He holds a B.S. degree in applied science and engineering from the U.S. Military Academy, an M.S. degree in mechanical engineering from Rennselaer Polytechnic Institute, and an M.S. degree in national resource strategy from the Industrial College of the Armed Forces.

(E-mail address: KotchmanD@tacom.army.mil)

COL Robert Reyenga, USA, is the Chief of the Acquisition Management Branch of the Total Army Personnel Command, Alexandria, VA.

(E-mail address: reyengar@hoffman.army.mil)

Lt Col Terence Szanto, U.S. Air Force, is the logistics and nuclear policy planner for the U.S. Delegation to the NATO Military Committee in Brussels, Belgium.

(E-mail address: szantos@natosabxlexch1-brussels.army.mil)

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ENDNOTES

1. Quoted by Permission, Brigadeer General Michael Hough, USMC, deputy program manager Joint Strike Fighter, during an address to the ICAF Acquisition Class, March 19, 1999.

2. DoD Total Ownership Cost (TOC) is the sum of all financial resources necessary to organize, equip, train, sustain, and operate military forces sufficient to meet national goals in compliance with all laws, all policies applicable to DoD, all stnadards in effect for readiness, safety, and quality of life, and all other official measures of performance for DoD and it components.

3. The Grizzly Program is a U.S. Army program. The Grizzly is a complex obstacle breaching system based on the MI Abrams tank chassis. It is designed to support combined arms maneuver operations.

4. For a short description of each, see GSA's *Information Technology Capital Planning and Investment Guide*.

THE EVOLUTION OF 21ST CENTURY ACQUISITION AND LOGISTICS REFORM

Paul J. McIlvaine

The United States has changed its military strategy and stepped up the use of its existing military forces without a major defense budget increase. A host of new initiatives are under way to generate the cost savings necessary to continue force modernization without a major budget increase. Reforms so far have primarily focused on the acquisition and logistic parts of the problem. Financial, contractual, and sustainment reforms are needed in order for acquisition and logistics reform (ALR) to achieve its full potential.

Joint Vision 2010 (Shalikashvilli, undated) has outlined a significant change in U.S. military strategy. It describes a transition from a forward-deployed force (with stockpiles of materials and permanent troops located in anticipated trouble spots) to a largely CONUS-based force with a power projection capability (achieved through rapid strategic mobility and reduced logistics tails). Scenarios in which U.S. forces are deployed have expanded from major wars to a broad range of deterrent, conflict prevention, and peacetime activities—in concert with our friends and allies in almost all operations. The Joint Chiefs of Staff (JCS) Focused Logistics Roadmap integrates a host of initiatives (rapid distribution and response, total asset visibility, information fusion, etc.) designed to improve logistics for the warfighter in support of *Joint Vision 2010*.

Defense acquisition reform efforts are under way to cope with this change in military strategy. Due to the high cost of supporting existing systems, the "spill-over" of acquisition reform into the logistics arena was a natural follow-on. It seems as if more Department of Defense (DoD) logistics changes have been proposed in the past three years than in the previous 30 years; some say that we've just "scratched the surface." The Section 912(c) DoD Product Support Reengineering Implementation Team, in its July 1999 *Product Support for the 21st Century* report, identifies 300 DoD logistics and product support initiatives (Gansler, 1999).

In recognition of the inseparability between ALR efforts, the fiscal year (FY) 2000 National Defense Authorizations Act changed the title of the Under Secretary of Defense for Acquisition and Technology to the Under Secretary of Defense for Acquisition, Technology and Logistics (USD (AT&L)).

Current Defense Needs

Current U.S. defense needs require both increased operations and continued modernization. The classical, relatively easy approach to achieving the need has been to increase the defense budget. Contemporary political pressures, however, have forced the search for more economical alternatives.

One alternative that immediately comes to mind is to prioritize and limit operations. This will immediately reduce logistics costs—the greatest component of the defense budget. Yet, as Representative George R. Nethercutt, Jr. (1996) observed in *National Defense*, "The Defense Department has been involved in more deployments in the past 7 years than during the entire Cold War." General Erik Shinseki (Chief of Staff, Army), in a February statement before the House Armed Services Committee, observed that "Since 1989, the average frequency of Army contingency deployments has increased from one every 4 years to one every 14 weeks."

Maintaining near-term readiness of existing systems while continuing modernization efforts and reducing infrastructure remains a serious challenge. DoD requests for additional base realignment and closures (BRACs) have yet to happen. Current operating tempos dictate that current operations take precedence over future modernization. Therefore, it was no surprise that the Joint Aviation Logistics Board (JALB) June 1999 report on *Commercial Support of Aviation Systems* states that discretionary procurement accounts dropped by 53 percent since 1990, while operations and maintenance activity declined by only 15 percent (Joint Aeronautical Commanders' Group, 1999). This is effectively delaying replacement of existing systems.

Secretary of Defense William Cohen, in the May 1997 *Report of the Quadrennial Defense Review*, observed that "Today, the Department is witnessing a gradual aging of the force." This lends credence to the statement in a 1994 issue of *Army RD&A Bulletin*: "In actuality, our military hardware is now on a replacement cycle of about 54 years—this in a world where technology typically has a half-life from 2 to 10 years" (Augustine, 1994).

Figure 1 shows that total operating and support costs (for U.S. Mail processing automation equipment whose annual support costs equal approximately 18 percent of acquisition cost) are service-life dependent and can approach 98 percent of total life-cycle cost (LCC) if the equipment is kept in service for 54 years. Thus, any DoD efforts to reduce LCC must establish operations and support as a prime consideration in designing a new system or improving an existing system.

The 53 percent drop in procurement over the last 10 years has significantly weakened the Defense Industrial Base. Northrup Grumman chief executive officer Kent Kresa stated in March that "The trouble with our industry is, we have virtually nothing new. Where we used to have a new [Pentagon weapons system]

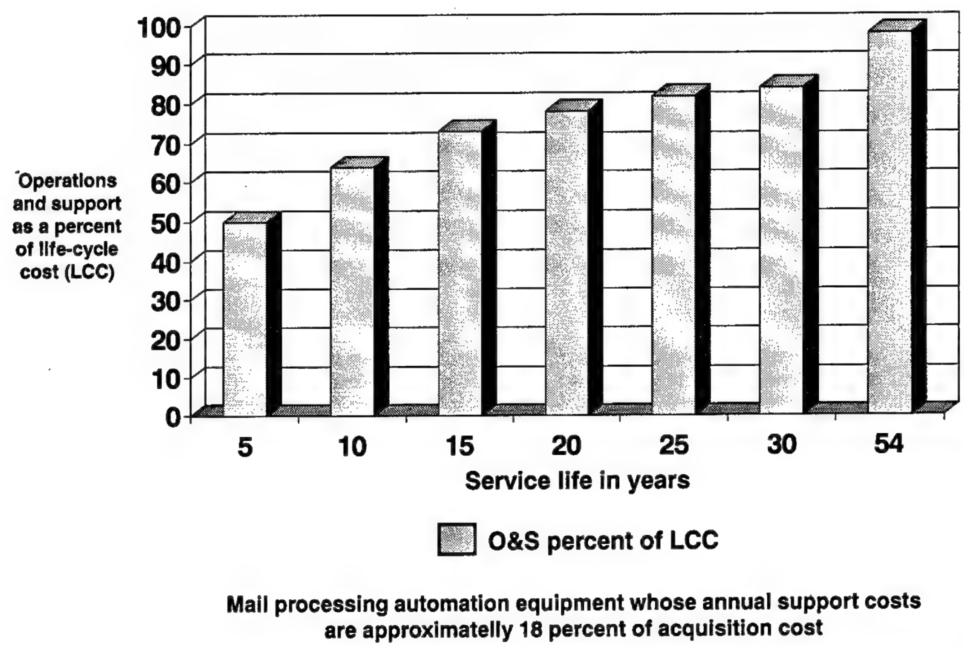


Figure 1. O&S is Service-Life Dependent

coming along, a major system, every year or every other year, now we're talking about every decade. Maybe every two decades... And if you happen to be an airplane builder, once the Joint Strike Fighter gets finished, what's next? So how do you [attract] the young person who wants to build airplanes, who'll never have an opportunity in his lifetime to build an airplane?" (Schneider, 2000).

One response to this gradual decrease in modernization is to exhort managers to "do more with less." But you simply cannot do more of the same with less; you either do more with more, or less with less. The remaining alternative is to change procedures and processes to increase efficiency and effectiveness.

CURRENT INITIATIVES

Acquisition and logistics reform deals with the modernization dilemma by changing procedures and processes to increase efficiency and effectiveness. Non-value-added effort is eliminated. The goal is to free funds to accomplish needed modernization. Craig Olson, in a spring 2000 *Acquisition Review Quarterly* article, states that the challenge simply cannot be met short of a revolutionary change in the present acquisition force structure. *DSMC Press Technical Report TR-1-99* states that it is too early to measure the success of acquisition reform (Reig, Gailey, Swank, Alfieri, and Suycott, 1999). Only projections can be made at this point.

Official DoD Photo

The B-52H of the 20th Bomb Squadron "Buccaneers" from the 2nd Bomb Wing, Barksdale, Louisiana.

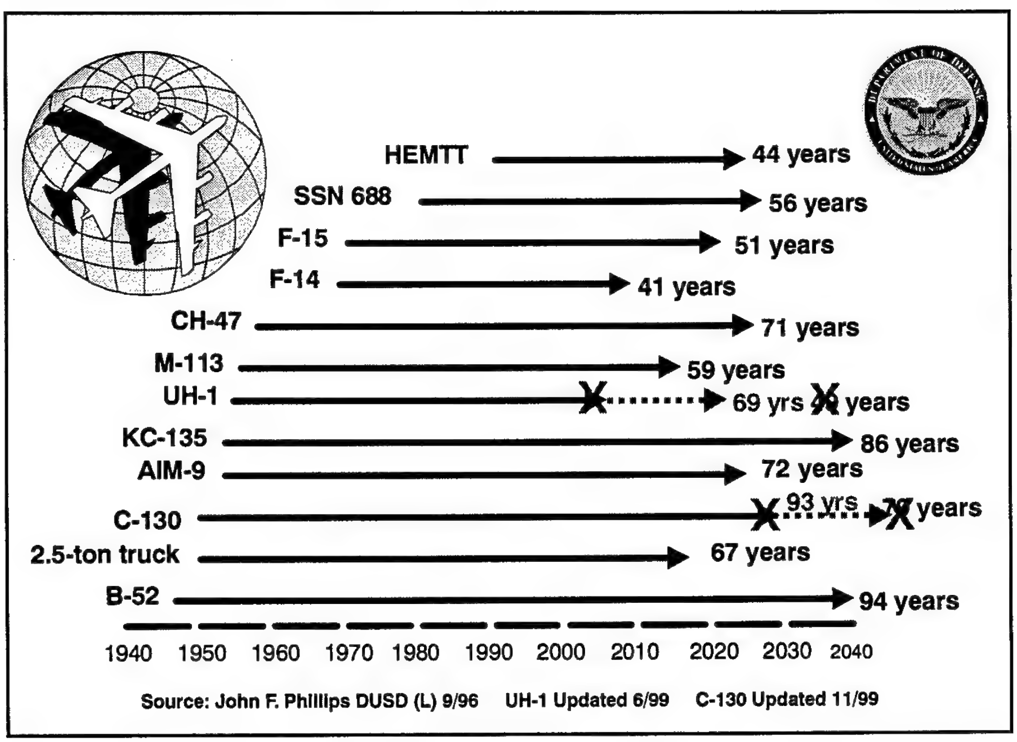


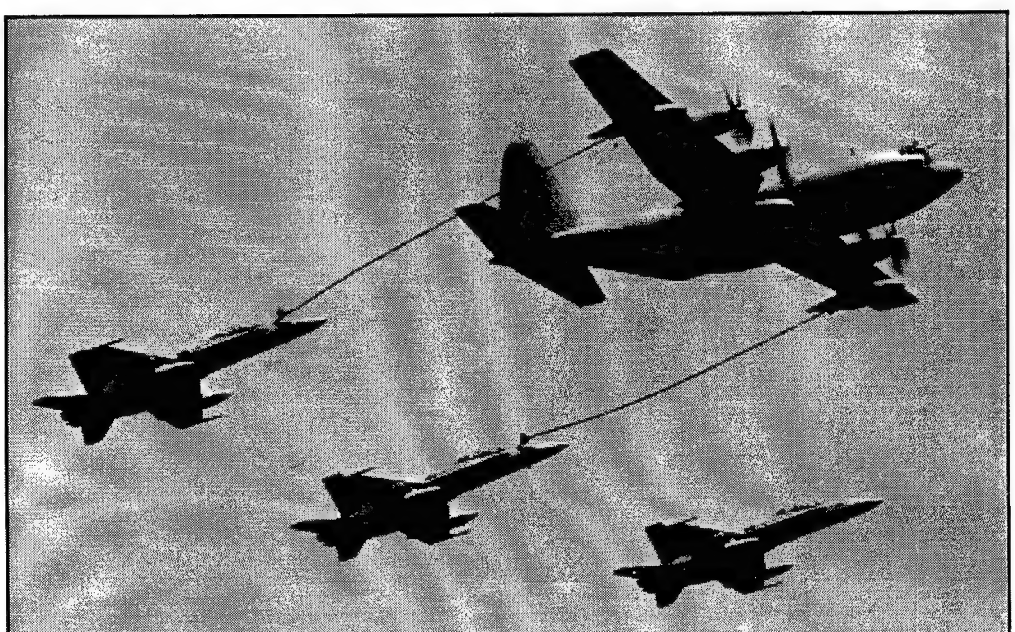
Figure 2. Defense System Life Cycles

To adequately address ALR, we need to adopt a representative time. This time perspective is the entire system life cycle, which spans research, development, test and evaluation, manufacturing and production, deployment and materiel fielding, operations and support, modifications and product improvements, and ultimate disposal, recycling, or demilitarization of the system.

Figure 2 illustrates this time perspective for a number of representative defense systems. The system life cycle equals acquisition time (the time from conception of a weapon system through the initial deployment of a small quantity) plus service life (the time from initial operational capability to disposal, demilitarization, or recycling of the last system). Jacques Gansler, in *Affording Defense*, observes that acquisition time varies in the range of 11 to 19 years. By assuming a 15-year acquisition time and a 54-year service life, a representative time perspective for defense systems can be defined as approximately 70 years. Some systems, such as the B–52 and C–130, have projected system life cycles in excess of 90 years.

The DoD Logistics Strategic Plan

In August 1999, Jacques Gansler USD (AT&L), promulgated the year 2000 edition of the *DoD Logistics Strategic Plan* to modernize our logistics systems and improve support of our 21st century warfighters.



Official DoD Photo

A US Marine C–130 "Hercules" performs a refueling mission during an Air and Amphibious Beach Assault exercise.

Logistics redundancy and duplication are time-honored—albeit inefficient—methods used in the past to support acquisition of some state-of-the-art equipment that has been largely "long on performance, but short on supportability." Although multiple examples of cost-effective defense systems exist, the fact is that logistics accounted for 64 percent of fiscal year 1997 DoD total obligation authority (or its new synonym: DoD total ownership cost).

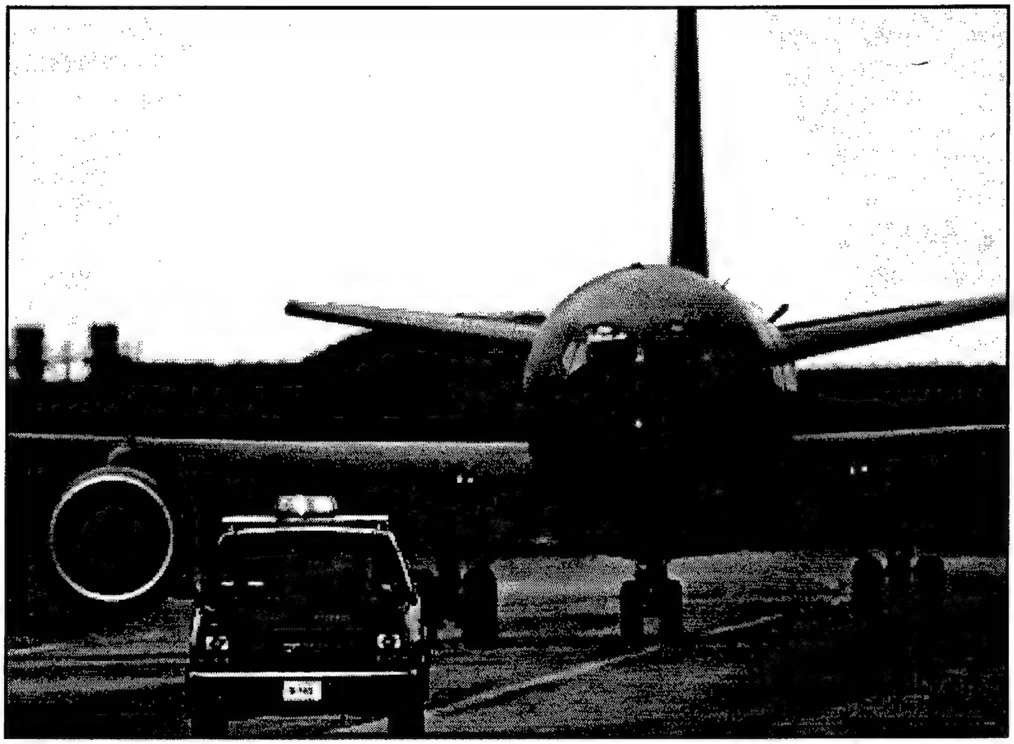
Gansler expressed his dissatisfaction with this current state of affairs in a January 20, 1999, letter ("Into the 21st Century: A strategy for Affordability"). He set a goal to reduce the funding required by logistics from 64 percent of total obligation authority in fiscal year 1997 to 62 percent by fiscal year 2000, to 60 percent by fiscal year 2001, and a stretch target of 53 percent by fiscal year 2005. To achieve this requires a wholesale recognition that operations and support represent a significant cost driver which requires prime consideration early and throughout the design and development of a new or improved defense system.

Shortcomings of Current Measures of Success

In wartime, the cost of weapon systems has historically remained a secondary issue. The United States traditionally provides what it takes to support our troops. During extended peacetime, however, the

Official DoD Photo

Aviation Ordnancemen load an AIM-9 "Sidewinder" missile on an F/A-18 "Hornet" attached to the "Rampagers" of Strike Fighter Squadron Three on the flight deck of the aircraft carrier USS *George Washington*.


Official DoD Photo

A KC-135 follows a lead vehicle back to the Alpha ramp at Grand Forks Air Force Base, N.D. for a regeneration sortie and aircrew servicing.

cost of defense systems tends to dominate debate. Myopic views of cost result in an excessive focus on yearly expenditures (the current budget) for defense programs. A broader strategic perspective involves the use of LCC.

The other measure of defense systems success is effectiveness when used. Despite the fact that the majority of a defense system's life cycle is spent in peacetime, we must design weapon systems for the worst-case environment—war. But war is the world's most uneconomical undertaking.

If we combine the two measures above, the "bottom line" of all improvement efforts can be summed up as cost-effectiveness. But cost-effectiveness is a judgment call—a subjective versus objective measure. This ensures that continued controversy will remain an integral part of the defense acquisition process now and in the future.

The Worst and Best Practices – A Comparison

The best illustration of new ALR efforts is to compare the "worst practices" of the 1960s through the 1980s with the "best practices" (including ALR initiatives) of the 1990s through 2010 and beyond. Figure 3 illustrates this comparison over a 70-year lifespan, including each "cradle-to-grave" year drawn to scale. This is the time needed to demonstrate

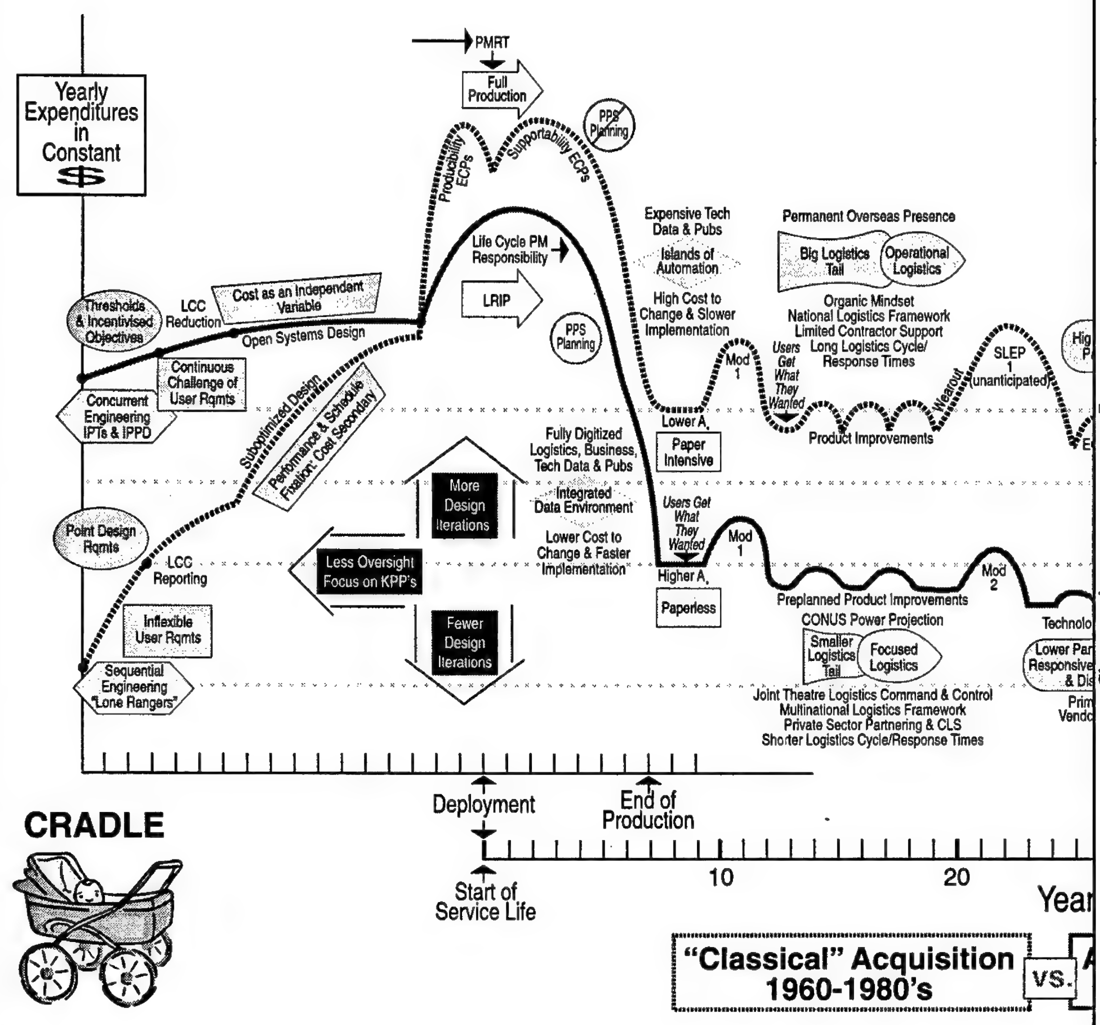


Chart continues across to page 7.

Please address all improvement suggestions on this chart to:
Paul McIlvaine
Email: MCILVAINEP@dsmc.dsm.mil
Phone: (703) 805-4660

Figure 3.
21st Century Acquisition and Logistics Reform for a Typical Program

Chart continues from page 6.

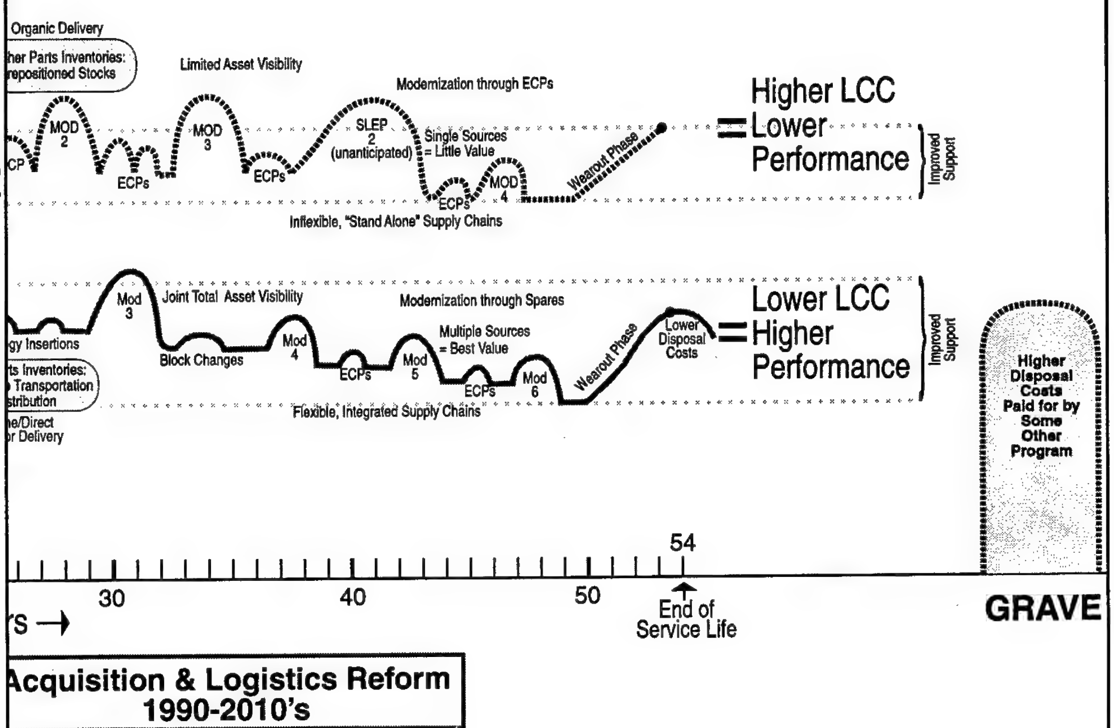


Figure 3 (continued).
21st Century Acquisition and Logistics Reform for a Typical Program

how well today's ALR efforts achieve their objectives.

The ordinate represents yearly expenditures on a constant dollar basis. Thus, Figure 3 as a hypothesis only addresses the economic success of ALR. By following the money from cradle-to-grave, we can illustrate the economic success of a "reformed" program, in which identical system effectiveness is assumed. Consequently, the measure of the economic success of ALR is minimizing the area under the curve (LCC—or its new synonym, defense systems total ownership cost).

The Worst Practices of the 1960s through the 1980s

The engineer in the 1960s through 1980s could be dubbed "The Lone Ranger." This engineer practiced the art of sequential engineering: First, design a system to work and meet or exceed all point design requirements. LCC—a minor concern—was dutifully reported as the result of design. Subsequently, design engineers addressed manufacturing and producibility. If "show-stopping mistakes" were identified (such as designing a wing 2 inches longer than the largest fixture in the tool inventory), then a redesign or engineering change was made, requiring more money and time.

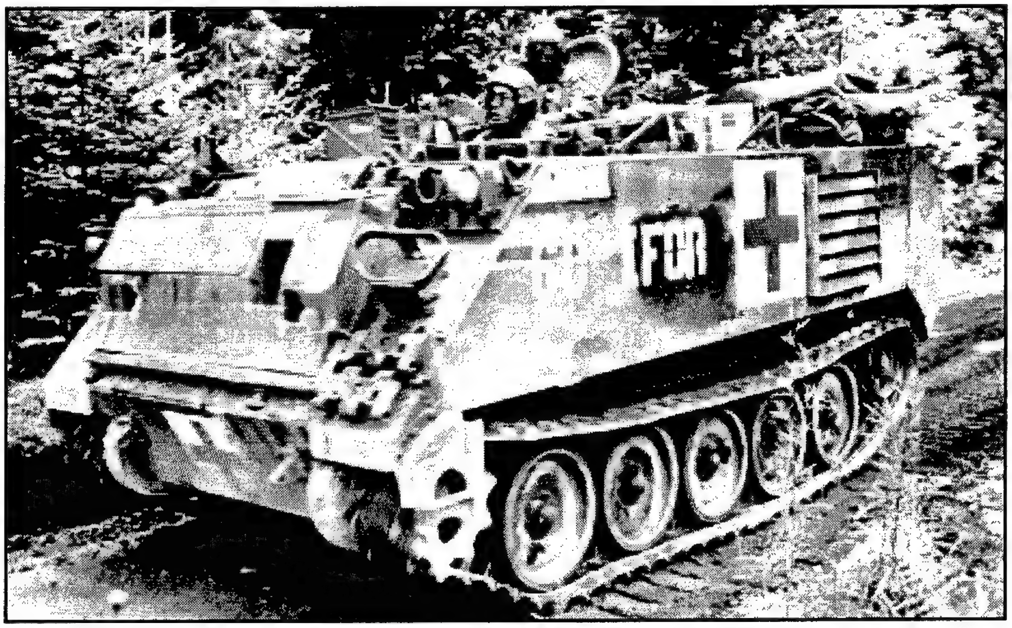
"The engineer in the 1960s through 1980s could be dubbed 'The Lone Ranger.'"

Logistics considerations then followed, demonstrating the attitude that the "loggies" would simply support whatever the design engineers created. Their measure of worth was dealing with shortsighted design decisions, and keeping systems (no matter how good or bad) running in the field. If show-stopping mistakes were identified (such as inaccessible parts requiring periodic replacement), then a redesign or engineering change was made, again requiring more money and time.

Following this path, the next major item was deployment—the system was turned over to the user. The user's last involvement with the program was in the "front end" requirements determination. User point-design requirements were considered inviolate and further discussions with users, or "challenges" of questionable user requirements during development, were frowned upon. If the user identified a show-stopping mistake upon receiving the deployed system (such as a nonwaterproof system targeted for exposed storage), then an engineering change was incorporated, again requiring more money and time. Alternately, if the change was not made, then the tactical and operational logisticians were sent scurrying to find unplanned, unbudgeted, covered-storage space for the system. And eventually, after a number of changes or other accommodations (collectively called MOD 1 or the A Model), the user got what the user wanted—sort of.

The steps in sequential engineering could be dubbed re-engineering or, better yet, "getting it right the second, third and fourth times." Too often, the downstream result was lower operational availability [readiness] at higher cost.

This paper-intensive, iterative process resulted in "islands of automation" for each functional discipline, a high cost to change, and slower implementation. A general defense "rule of thumb" was that



Official DoD Photo

An M-113 ambulance of the 1st Armored Division on a trail near site "Gator," Bosnia-Herzegovina.

technical manuals averaged $1,000 per paper page to change or update. During visits to operating bases, I personally observed maintenance technicians with handwritten notebooks in which they documented their "tricks of the trade." These notebooks helped them to better deal with problems that were inadequately described in the official technical manuals or ignored by the designers.

After deployment, the program manager executed a "program management responsibility transfer" to another organization, usually identified as a "logistics command" or equivalent. And the original program management team returned to new system development to again repeat the process. The receiving command then performed the function of program management—often mislabeled as "logistics management"—for the remainder of the system life cycle.

This mislabeling was due to the one certainty in acquisition—constant change. Program management of a brand new system includes the functions of design, test, production, fielding, operations and support, and eventual disposal. Logistics management primarily centers on the function of support or sustainment. After deployment, a defense system will certainly face change. Modifications include the functions of design, test, production, fielding and installation, operations and support, and eventual disposal—virtually identical functions of program management. Thus, the art and science of program management is the one function consistently performed throughout the entire system life cycle for both new starts and modifications to existing systems.

Systems produced via sequential engineering usually needed long, big, logistics tails to compensate for design short-

comings. An organic mindset usually permeated all logistics thinking and planning. The politically correct language to describe contractor support was "interim contractor support"—even if it lasted for decades. Higher parts inventories were pre-positioned within "arms length" to compensate for long logistics cycle and repair times (with great distance between places of use and repair). Organic delivery had to wait its turn as a "competing priority." Limited asset visibility confused and obfuscated logistics efficiencies by people not knowing where a part was in the pipeline or warehouse, or its condition. Supply chain management under this scenario is and was haphazard and inefficient. The net result was usually lower operational availability (synonym: readiness) at a greater cost.

"Systems produced via sequential engineering usually needed long, big, logistics tails to compensate for design shortcomings."

But the popular method to deal with low operational availability and high costs was to change the system. The quest to redesign is aptly named. The goal was to make the system do what it should have done in the first place. Unplanned product improvements and engineering change proposals were legion—especially as new technology allowed both performance improvement and support improvement.

As time marched on, however, the system eventually entered the wearout phase—the end of its service life. Many sequentially engineered systems were designed for service lives of 15 or 20 years, at which point the replacement systems were planned to arrive and allow smooth transition from old to new systems before the added costs of wearout. This planning optimism could result in disappointment if replacement systems were still mired in the early acquisition phases—years from deployment. In this case, the only practicable alternative was to institute an unplanned service life extension program (SLEP). This could prove quite costly if the system was not originally designed for rebuild—as in many cases.

But given enough time and money, "anything could be accomplished." Besides, the political visibility of modification programs has traditionally been less than new starts. Thus, the A model, B model, etc., became the modernization norm as technology continued its inevitable march forward. With increased service lives becoming commonplace, at least one or two unplanned and expensive SLEPs could be expected for many typical legacy systems. Gansler, in *Affording Defense*, speaks of the "...tradition of keeping equipment in the field approximately twice as long as it was initially planned..." (1989).

After production termination (postproduction support), one of the major downsides of new technological improvement became evident. Sole source suppliers of unique spare parts for legacy defense systems that were no longer in production faced higher costs to produce fewer quantities when orders fell. Thus, suppliers were faced with decisions to either raise costs and keep their spare parts production lines open, or embrace new technology and cease production of the older technology. With little or no post production support planning—evidenced by sole sources of supply, high costs, slow

response times, and the like—the government was often faced with reverse engineering of replacement parts, life of type buys, unplanned depot overhauls, or system redesign. Advantages gained by improved technology (even with logistics benefits) could be more than offset by the difficulty of changing systems that were not designed for easy change.

Eventually, all systems reach the end of their economic or physical service lives, when replacing the system represents the most cost-effective alternative. Disposal of the legacy system is then addressed—usually for the first time. Museum donations, foreign military sales, retirement to Davis-Monthan Air Force Base, etc., represented relatively easy solutions to the problem.

Hazardous materials used in the original design of the system presented special problems. If additional monies could be found for this unplanned activity, proper disposal of hazardous materials was feasible. Shortsighted solutions to the problem involved burial in remote parts of military bases, burial at sea, or other environmentally unfriendly alternatives that are no longer acceptable. However, this previous practice allowed a quick, cheap, and easy end to the system as the program was terminated. Decades later, the legacy of shortsighted hazardous materials disposal became evident. But with no program around, it was likely that somebody else would have to bear the cost and danger of cleanup.

This rather pessimistic view indeed represents a compilation of "worst practices" for a theoretical program. In the early 1970s, my engineering supervisor once told me to "get real" and stop creating controversy and delay by trying to design it right the first time. He said the only way to build a defense system was to spend the money quickly, or some other program would "steal" it. If the design wasn't quite right the first time, you would eventually get the money and commitment to fix it later!

Unfortunately, the wisdom in his comments reflected the inflexibility of DoD's financial systems and the incentives and rewards in place at the time. Despite these shortsighted incentives, many programs in the 1960s through 1980s used different methods and better practices. These are the defense systems that are still in service today. Longevity is (and remains) the bellwether of a good system design.

> **"Eventually, all systems reach the end of their economic or physical service lives, when replacing the system represents the most cost-effective alternative."**

The Best Practices of the 1990s through the 2010s

Choices characterize the "front end" of modern acquisition practice. Computer-aided design, manufacturing and logistics tools allow faster computation of design tradeoffs, assessment of design alternatives, and completion of design—compared with previous manual practices. But these modern tools can be used in two ways:

Complete the Process Faster and at Lower Front-end Cost

Alternative 1 yields the most immediate and measurable results and is the

objective in stated goals to reduce cycle times. But the *DSMC Press Technical Report TR-1-99* states that the pre-1989 average duration of the engineering and manufacturing development phase was 6.5 years, rising to 8.7 years during the period 1993–1996, and dropping to 8.3 years in 1997 (Rieg et al., 1999). This data could lead to a conclusion of limited progress to date.

Complete the Process at the Same Speed and Cost, but Better

Alternative 2 is to complete the process in the same amount of time (by pursuing additional design iterations to yield a higher quality and reduced risk design) and at the same front-end cost (by reinvesting any front-end savings in high payoff areas for downstream cost reduction).

Alternative 2 has the potential to yield even greater LCC savings. This alternative makes comparisons much clearer, and it is depicted in Figure 3. If Alternative 1 were depicted, the gray line in the chart would move to the left (reduced cycle time) and move down (reduced front-end cost). Reduced oversight would have the same effect.

Since the one certainty in all of acquisition is constant change and inevitable technological progress, open systems design has emerged as one of the most intelligent design innovations in decades.

UH-1 Huey helicopters from the 37th Helicopter Flight prepare to land in a field during a simulated Launch Facility (LF) Recapture Exercise.

Open systems design recognizes that change is inevitable and seeks to establish system architectures and system designs with the flexibility and partitioning to facilitate future change to the maximum extent practicable. Where needed technologies have not yet matured, preplanned product improvements and technology insertions can be more easily implemented downstream with open systems design. This technique should prove to be of great benefit to systems design, production, and logistics support.

The engineer in the 1990s through 2010s could be dubbed "design team leader" or "systems engineer." This modern engineer practices the art of concurrent engineering (systematic consideration of all elements of the system life cycle—including manufacturing and support—from the beginning). Integrated product and process development (IPPD) is the predominant technique that simultaneously integrates all disciplines through the use of multidisciplinary teams in each area that ultimately has a hand in the acquisition and design process. This includes software engineers, production engineers, logistics engineers, test engineers, reliability engineers, contract specialists, financial managers, LCC analysts, user representatives, business managers, contractor personnel, and others.

The goal is a producible, supportable, cost-effective design that satisfies user requirements at the lowest practicable LCC. The objective is to "get it right the first time" through a series of design iterations—each of which yields a higher quality design. What we call show-stopping mistakes should be rare, since all participants in the process are team members from the outset.

Inflexible point design requirements have been replaced with thresholds (minimum acceptable values) and objectives (a more desirable value to work toward). This range of acceptable values allows enhanced design flexibility in making reasoned tradeoffs. Greater user involvement in all phases of the acquisition program allows continual dialogue and "challenge" of user needs to foster more intelligent design decisions.

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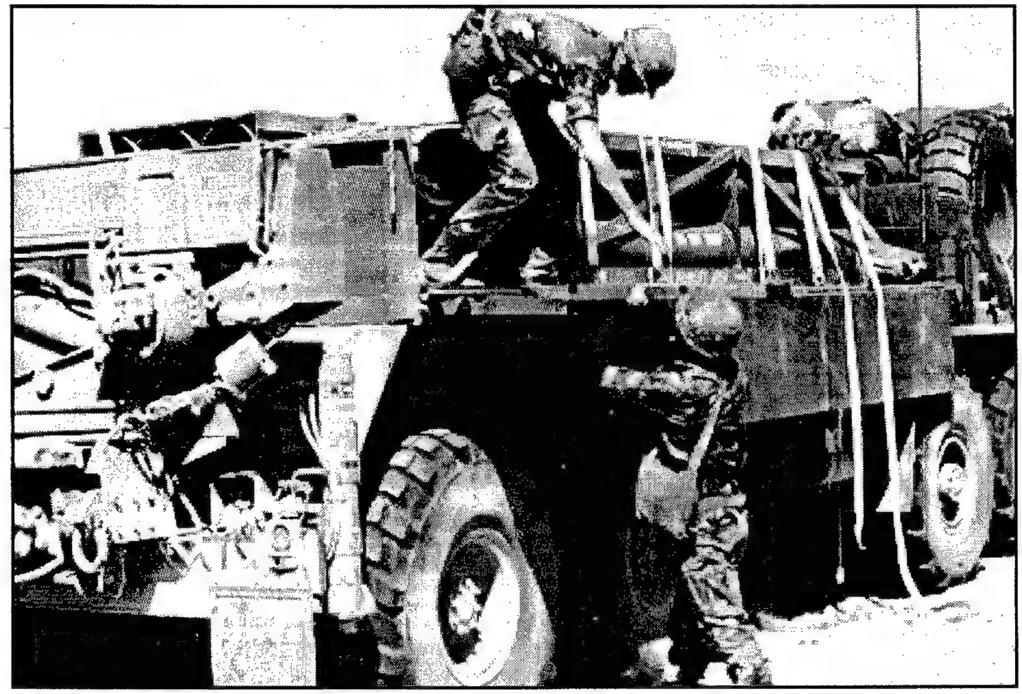
Cost as an independent variable (CAIV) methodologies are used to acquire affordable DoD systems by a better balance among performance, schedule, and LCC. Tradeoff analysis is repeatedly applied throughout the system life cycle as the key tool that results in LCC reduction—not just reporting.

The tendency of keeping defense systems in service at least twice s long as initially planned can be dealt with by more realistically designing systems for longer service lives or designing systems for periodic rebuild (if more cost-effective). Costly, unplanned service life extension programs can be radically reduced. Open systems design is expected to make modifications, technology insertions, and product improvements less expensive and faster to implement.

The measure of the worth of logisticians is no longer how well they deal with easily avoidable downstream problems (reactive problem solving). Proactive problem prevention is the primary goal and focus of the acquisition logistician.



Heavy Expanded Mobility Tactical Truck (HEMTT)

Problem solving for the tactical-operational logistician will never entirely disappear, but will be reduced to manageable proportions, due to greater logistics attention in the front end of the process.

Producibility and supportability Engineering Change Proposals (ECPs) are drastically reduced as a result of the continuous involvement of produciblity engineers and acquisition logisticians from the outset of the program.

The entire acquisition process will be tied together via an integrated data environment that allows all users real-time access to the data they need. Enhanced communication among program participants facilitates improved management. Lower cost to change documents and faster implementation (a.k.a. reduced cycle time) should become the norm, because of this paperless process.

As a result of continuous user involvement in the program, deployment can be expected to be much smoother. The user knows what to expect from the system and the developer knows how the user will operate and support this system.

The Section 912(c) report on *Program Manager Oversight of Life Cycle Support* identified 30 pilot programs to test the concept of the program manager assuming life-cycle system responsibility (PMOLCS Study Group, 1999). Presuming success, the program manager of the future can be expected to retain the life-cycle responsibility for the system subsequent to deployment. Field commanders and users will most likely continue their responsibility for the *present*—i.e., the readiness and sustainability of the fielded system. The program manager can be expected to assume responsibility for the

future—i.e., improvement of the system (to include the operational subsystem and the logistics support subsystem).

Systems designed and produced via concurrent engineering or IPPD usually need shorter logistics tails to accompany high quality designs. Partnering arrangements with industry for long-term life-cycle contractor support—governed by sensible "win-win" business relationships—will replace the "organic mindset." Necessary organic support is still retained for those functions defined as core.

Total asset visibility (TAV) provides users with timely and accurate information on the location, movement, status, and identity of units, personnel, equipment, and supplies. This tremendously increases logistics efficiency and supply chain management because all players in the process know where each part is (pipeline, warehouse, contractor plant, etc.) and in what condition each part is (ready for installation, undergoing repair, etc.). Rapid transportation and distribution (coupled with prime or direct vendor delivery) results in lower total parts inventories and improved logistics responsiveness. The net result will be higher operational availability (readiness) at lower cost.

Mutually acceptable measures of effectiveness (MOEs) in a performance-based environment are the basis upon which sound business relationships and partnering agreements are built. Defense contractual arrangements in the future will de-emphasize units repaired per month, inventory quantities, etc. New defense contractual arrangements will evolve to performance-based logistics in which we buy operational availability or customer wait time and mean logistics delay time.

Costs per operating hour is another MOE, common in commercial industry, that can be expected to see increased Defense use in the future. Incentivization of improvements to systems and subsystems will be the norm in which contractors can reap additional profit by delivering added amounts of "goodness" in systems.

A single maintenance data collection system among all the services must evolve in order for ALR to reach its full promise. Accurate and timely field data is the cornerstone upon which sustaining engineering efforts assess current fielded system effectiveness and address prioritized improvements to both the system and its support.

As systems age, multiple sources of supply are still available because fewer single-source, single-application subsystems and components were used in the basic system design. Modernization through spares (MTS) is a strategy of technology insertion and the use of commercial products, processes, and practices to extend a component's useful life or improve its reliability. MTS can extend a defense system's useful life by dealing with the problem of newer technology supplanting the older technology in legacy defense systems. Good, solid post-production support planning will not preclude all modernization and supply problems, but instead will reduce the remaining problems to manageable proportions.

"Systems designed and produced via concurrent engineering or IPPD usually need shorter logistics tails to accompany high quality designs."

As the system enters the wearout phase, disposal plans are put into action and disposal budgets are executed. Fewer hazardous materials should be used in the original design. Disposal planning for those that were used can be updated before the system is ultimately disposed.

This rather optimistic view represents "best practice." In about 70 years (the life cycle for the average defense system), we will be able to accurately measure the results of today's ALR efforts.

SUMMARY

Exhortations for government to "adopt commercial methods" and "do it like industry does it" are common. The Section 912[c] report on *A Plan to Accelerate the Transition to Performance-Based Services* reiterates the future projection that "Government acquisition spending will continue to be used to foster socioeconomic goals" (Anderson, 1999). But the report goes on to observe that "Because the goals of a DoD source selection differ from those in a commercial source selection, the most aggressive commercial methods are not appropriate for DoD use." Thus, industry has different goals, fewer constraints, and more flexible financial systems that are, in many ways, less burdensome than those used by government. Industry does not always do it faster, cheaper and better than government—a more accurate statement might be that industry does it differently than government.

"Industry does not always do it faster, cheaper and better than government—a more accurate statement might be that industry does it differently than government."

"Pay me now or pay me later" remain the chief options in DoD acquisitions. Past defense acquisition systems tended to incentivize the "pay me later" option—evidenced by the high cost of operating and maintaining our existing systems. Defense ALR efforts are simply asking for a more reasoned tradeoff among the "pay me now or pay me later" alternatives for future systems, while we struggle with the legacy of our past decisions.

Best commercial practice involves giving good program managers a clear job with wide latitude, minimal oversight, and considerable flexibility in making investment decisions in their commercial product programs, while holding them accountable for results. Investing "up front" monies to avoid "downstream" expenditures must always be the subject of a serious business case analysis resolved through tradeoff decisions involving a long-term perspective. Government program managers for defense programs need that same latitude, flexibility, and accountability.

ACQUISITION AND LOGISTICS REFORM (ALR) RECOMMENDATIONS

Acquisition and logistics reform efforts to date have made considerable progress and hold great promise. However, much work remains to be done in order to achieve the full potential of these reforms. Below are six areas where improvements can be made.

First, government contracting tools need to change to reflect the new reality. DoD Directive 5000.1 and DoD Regulation 5000.2-R direct that long-term, life-cycle contractor support is the preferred

method of logistics support. The JALB Report *Commercial Support of Aviation Systems* cites the framework of *the World Airlines and Suppliers Guide:* The maximum parts cost guarantee is an agreement whereby suppliers provide a parts cost (Joint Aeronautical Commanders' Group, 1999).

To adopt this standard commercial practice in government may be viewed as limiting competition. Long-term, life-cycle contractor support requires innovative multiyear service contract arrangements, possible statutory changes, and logistics contractual strategies that encompass longer defense service lives (54 years, for example). In current practice, government contracts are of much shorter duration and can hamper government program managers from more efficiently executing life-cycle responsibility.

Second, a long-term financial perspective (approaching 54 years) is necessary to implement ALR. The planning, programming, and budgeting system (PPBS) is the Defense Department's financial system that provides the "fuel" to make ALR work. But the PPBS looks forward about six years at most. Paul Mann, in *Aviation Week and Space Technology* (2000), observes that "...unsynchronized Pentagon/congressional budget cycles, result in artificial cost projections and an acquisition culture of intellectual dishonesty." Thus, government financial reform has not kept pace with ALR efforts.

Third, government program managers who can obtain a great return on investment of "up front" RDT&E monies to significantly reduce downstream operations and maintenance (O&M) monies are still thwarted in their attempts to make serious tradeoff decisions. "Colors of money" and the intractability of the current PPBS may defeat a compelling government business case analysis for up-front investment to greatly reduce downstream expenditures. A commercial producer would readily adopt this same business case analysis. Procedures that allow program managers to retain and reinvest savings (or portions thereof) in their programs are needed. In today's environment, government program managers are still incentivized to minimize expenditure of scarce RDT&E and procurement funds; i.e., their current budgets—not optimize LCC.

Fourth, commercial practices and use of commercial or nondevelopmental items, if properly applied, are great methods of improving processes and reducing costs. Commercial practices are different from defense practices, however, and usually involve shorter life cycles with little customer control. So customers must have the flexibility to react to the market decisions of their commercial suppliers. For example, when a commercial supplier decides that new technology no longer makes it cost-effective to support a legacy system, customers are forced to either set up their own logistics support or replace their older systems with the latest technology.

"'Colors of money' and the intractability of the current PPBS may defeat a compelling government business case analysis for up-front investment to greatly reduce downstream expenditures."

But the government financial system dictates the use of different colors of

money for each alternative. If the government program manager expected the technology cycle to be longer and budgeted operations and maintenance monies to support a legacy system, these budgeted monies (even if adequate to replace the older system with the latest technology) cannot be used to finance procurement of the latest technology system. They can only be used to operate and maintain the older system. This current state of affairs will often force government program managers into "shortsighted" and uneconomical decisions dictated by an inflexible PPBS, rather than by logic.

"It takes time to spend money wisely; but, in the current environment, slower, wiser spending is impracticable."

Fifth, "haste makes waste." When constant defense budget turbulence threatens to decrease or eliminate needed program funds, Industry reacts by hesitating to make any long-term capital investment in the program. Program managers react to this financial instability by hurrying to spend monies before another budget cut. It takes time to spend money wisely; but, in the current environment, slower, wiser spending is impracticable. An old friend and colleague of mine (currently serving as a government program manager) recently commented that the most common question he is asked at reviews is "What are your obligation and expenditure rates?"

This budget turbulence is not limited to DoD. A front page *Washington Post* article on a lost Mars polar lander stated that "... NASA's efforts to tighten the budget screws and encourage certain kinds of risk taking—under a philosophy known as 'faster, cheaper, better'—finally went too far" (Sawyer, 2000). "...Managers may have failed to raise alarms more clearly up the chain of command because of concern that they would lose ground in the competition for tight funding..."

Sixth, past inattention to the sustainment and maintenance (operations and support) phase of the system life cycle has clouded the objectives of this phase: readiness and sustainment of the system, and improvement of the system (to include the operational subsystem and the logistics support subsystem).

In-service engineering analysis of fielded systems performance is hampered by "islands of automation" (that inhibit the free flow of information) and unique maintenance data collection systems that have evolved for each service. Greater program management, engineering, and logistics resources and attention devoted to this area will result in decreased LCC. Improved maintenance data accuracy, better data collection and dissemination efficiency, enlightened data reduction and analysis, prioritization of engineering improvements with both operational and logistics benefits, and better visibility into product support costs and logistics effectiveness are prerequisites to executing modern program manager life-cycle responsibility and achieving the objectives of this phase.

Conclusion

Much effort has been expended on ALR. Government financial systems, however, have not been reformed, and currently support the old way and worst

practices in doing business. Thus, ALR efforts will fail at worst and stumble at best under the statutes, policies, processes, precedents, and procedures of the current financial systems applicable to defense in the legislative and executive branches of government. Financial reform, contractual innovation, and other changes to provide defense program managers greater flexibility in the expenditure of funds and greater incentivization to minimize LCC is sorely needed to complete the transformation of the DoD acquisition and logistics system from the 20th to the 21st century.

Paul McIlvaine recently retired after 20 years as a professor of engineering management at the Defense Systems Management College (DSMC). Before joining DSMC, he served as project engineer, Naval Air Systems Command and acquisition project officer, Headquarters, Marine Corps. He holds a M.S. degrees in national resource strategy (National Defense University, Industrial College of the Armed Forces) and in administration (The George Washington University); and a B.S. degree in electrical engineering (Villanova University). He is a 1994 graduate of the Defense Acquisition University's Senior Acquisition Course.
(E-mail address: pjmcilva@erols.com)

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COST AS AN INDEPENDENT VARIABLE: *PRINCIPLES AND IMPLEMENTATION*

Col Michael A. Kaye, USAF, Lt Col Mark S. Sobota, USAF, David R. Graham, and Allen L. Gotwald

Cost as an independent variable is a key tool in the thrust to reduce total ownership cost for defense systems. While the need for CAIV is driven by cost constraints, success relies upon identification and use of viable performance, cost, schedule, and risk "trade space." The Air Force has integrated CAIV concepts with those in the Reduction in Total Ownership Program (R-TOC), and has published a comprehensive guidebook for better understanding.

The Defense System Affordability Council (DSAC) Strategic Plan established Goal 2 to lower the total ownership cost (TOC) of defense products. The plan further established separate, aggressive objectives under that goal for systems in acquisition and fielded systems. These goals are further emphasized in the draft new DoD 5000.1 and 2.

To provide a focal point on all reduction in TOC (R-TOC) efforts, encompassing weapon system, infrastructure, and indirect dimensions, the Air Force established an R-TOC program office (SAF/AQXT). SAF/AQXT and the authors collaborated to publish the R-TOC Guidebook, which integrated Cost as an Independent Variable (CAIV) and a comprehensive R-TOC process for fielded systems (1999). The R-TOC process relies on baselining operating and support costs, identifying TOC drivers, and identifying R-TOC opportunities. CAIV drives system design decisions by providing comprehensive information on alternatives and impacts.

Whereas CAIV and the R-TOC process have many principles in common, CAIV exerts the most leverage when it influences system design and the R-TOC process is most effective on fielded systems. The relationship is shown in Figure 1.

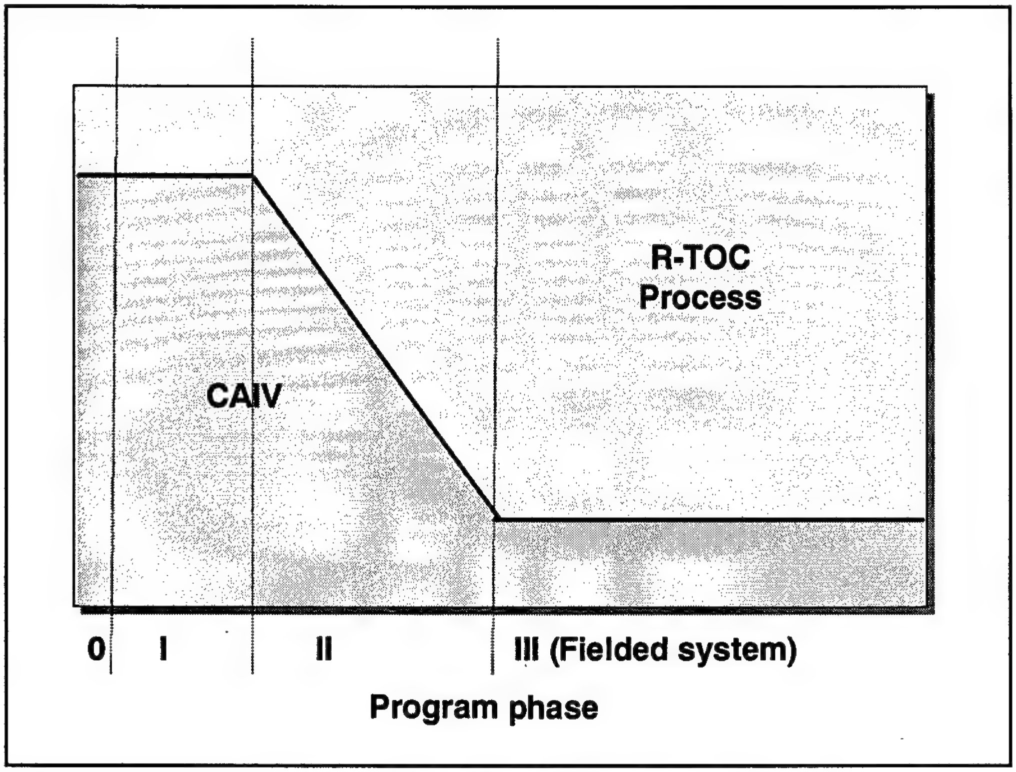

Figure 1. R-TOC/CAIV Effectiveness

CAIV Construct

CAIV is a key strategy for implementing R-TOC in the acquisition process, and is particularly effective during system development. Air Force Instruction (AFI) 10-601 (1998) defines CAIV as "the process of using better business practices, allowing trade space for industry to meet user requirements, and considering operations and maintenance costs early in requirements definition in order to procure systems smarter and more efficiently."

CAIV is founded upon two primary principles: First, system costs are constrained. Whereas some programs do obtain additional funding when needed, such funding is often at the expense of other programs or future modernization. Second, "trade space" is the foundation for smart decisions. Trade space is the range of alternatives available to decision makers. It is four-dimensional, comprising performance, cost (TOC), schedule, and risk impacts.

The Air Force established a set of tenets that are core to CAIV implementation. The concept of well-understood trade space is the capstone tenet that enables decisions critical to meeting user needs while reducing TOC. The remaining five tenets are the pillars that enable trade space to be defined and exploited. Figure 2, the CAIV model, depicts the relationship of the CAIV tenets.

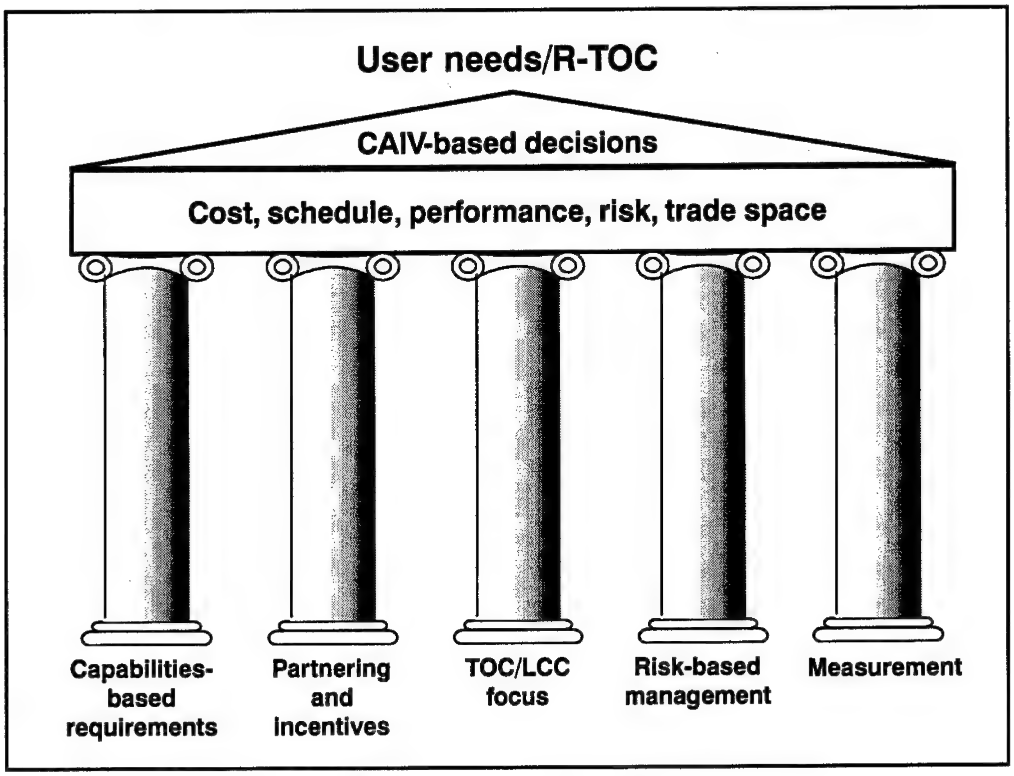

Figure 2. CAIV Model

TRADE SPACE

CAIV provides better support for critical decisions by identifying viable performance, schedule, cost (TOC), and risk trade space. Identification and use of viable trade space, or the range of alternatives, with full knowledge of real and potential impacts, is essential for making the right decisions to meet user needs while reducing TOC. CAIV employs a hierarchy of cost reduction opportunities and tradeoffs to meet aggressive cost targets, first looking to improve acquisition and sustainment efficiencies, then scrutinizing noncritical requirements. Tradeoffs of critical performance requirements are only to be addressed as a last resort, with the agreement of the Milestone Decision Authority and user.

Trade space is commonly defined by alternatives in terms of the performance, cost, and schedule impacts that each alternative presents. Risk must also be included in two ways. First, risk is a fourth dimension in the trade space, recognizing that critical decisions may be driven by the risks of certain alternatives. Second, risk actually "discounts" the anticipated performance, cost, and schedule options; in other words, it lessens the trade space to ensure a decision maker does not trade away something that may not be attainable. For example, assume you have a

system with anticipated range of 2000 miles versus a requirements threshold of 1500 miles. You could trade away up to 500 miles of range for a fully tested, validated system and still meet threshold. However, you definitely would not trade away 500 miles of range at the beginning of program definition and risk reduction (PDRR), when there are potential weight growths, fuel consumption increases, etc.

Figure 3 portrays the cost-performance trade space for a key performance parameter (KPP), characterized by threshold and objective values. Note that Figure 3 shows a "risk reserve" line to depict the amount that the trade space is restricted, to prevent trading away what is not yet realized. The "solution set" line represents the optimum cost-performance combinations: Points in the shaded region are solutions, but for any given point, either more performance for the same cost or the same performance for less cost is possible.

The trade space is of course multidimensional, corresponding to the number of KPPs. Tradeoffs can be performed at many levels. In the example above, where a KPP is involved, the user must agree to the tradeoff. When a contractor has configuration control below the "A Spec," then the contractor can make tradeoff decisions as long as the A Spec is met. The key is that the decision maker must fully understand impacts on the other elements, especially cost (TOC), in the trade space.

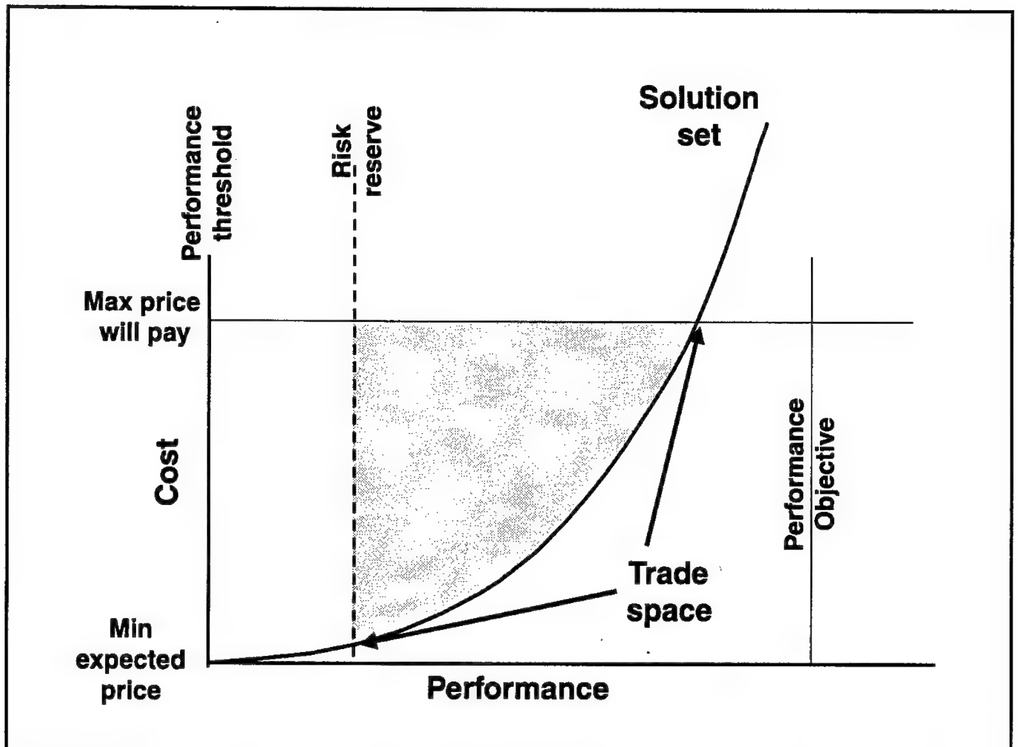

Figure 3. Cost-Performance Trade Space

Capabilities-Based Requirements

CAIV relies upon capability-based requirements. Implementation requires the user to define capability-based requirements, stating what the system needs to do instead of how to build the system and how subsystem allocations are made. Such definition allows the system development team flexibility to define a best-value system meeting user requirements. This requires the development of operationally-oriented performance requirements with a minimum number of KPPs. Requirements-setting authorities must take special efforts to exclude requirements not directly contributing to user needs. Prioritizing requirements helps exclude nonessential requirements while helping system developers maximize use of the trade space by focusing on characteristics contributing most to mission accomplishment.

The requirements process specifies that system requirements be reviewed at each milestone and revised as needed. But system performance thresholds defined at Milestone I (MS I), prior to Phase I trade studies, may be difficult to change in later reviews. That is the most important reason for introducing the cost dimension into the requirements-setting process as early as possible. Beginning with realistic and feasible levels of requirements, within the best available measures of cost estimation, provides the ability to identify a realistic performance requirements baseline. Through CAIV trades, the program can take advantage of alternative approaches and designs to achieve higher levels of performance at the same or lower levels of cost as more information allows cost estimates to become more refined and accurate. Staying flexible in the finalization of requirements is important, as emphasized in the draft new DoD 5000.1 and (2000).

The operational requirements document (ORD) I should identify system characteristics and define threshold ranges required for user effectiveness and be treated as interim versus final. Warfighters and users use mission effectiveness and cost performance analyses as key parts of the analysis of alternatives (AoA). When the preferred approach is identified, users employ mission effectiveness analysis and CAIV principles to set initial weapon system requirements, based on the best insight available to TOC. As a result, ORD I should include TOC objectives.

"Warfighters and users use mission effectiveness and cost performance analyses as key parts of the analysis of alternatives (AoA)."

Phase I trade studies should provide requirements-setters sufficient insight to TOC/LCC impacts for them to set specific threshold levels that ensure both mission effectiveness and affordability. During Phase I, the weapon system IPT uses CAIV to define TOC impacts and conduct trade to refine requirements studies focused on design and sustainment. The derived data enables users. The IPT ensures a continued ability to meet baseline requirements while adapting to requirements evolutions that drive system modifications. Finalization of requirements from the ranges defined in ORD I should occur at this time. Both the Joint Strike Fighter (JFS) and Advanced Amphibious Assault Vehicle (AAAV) have employed this evolutionary approach.

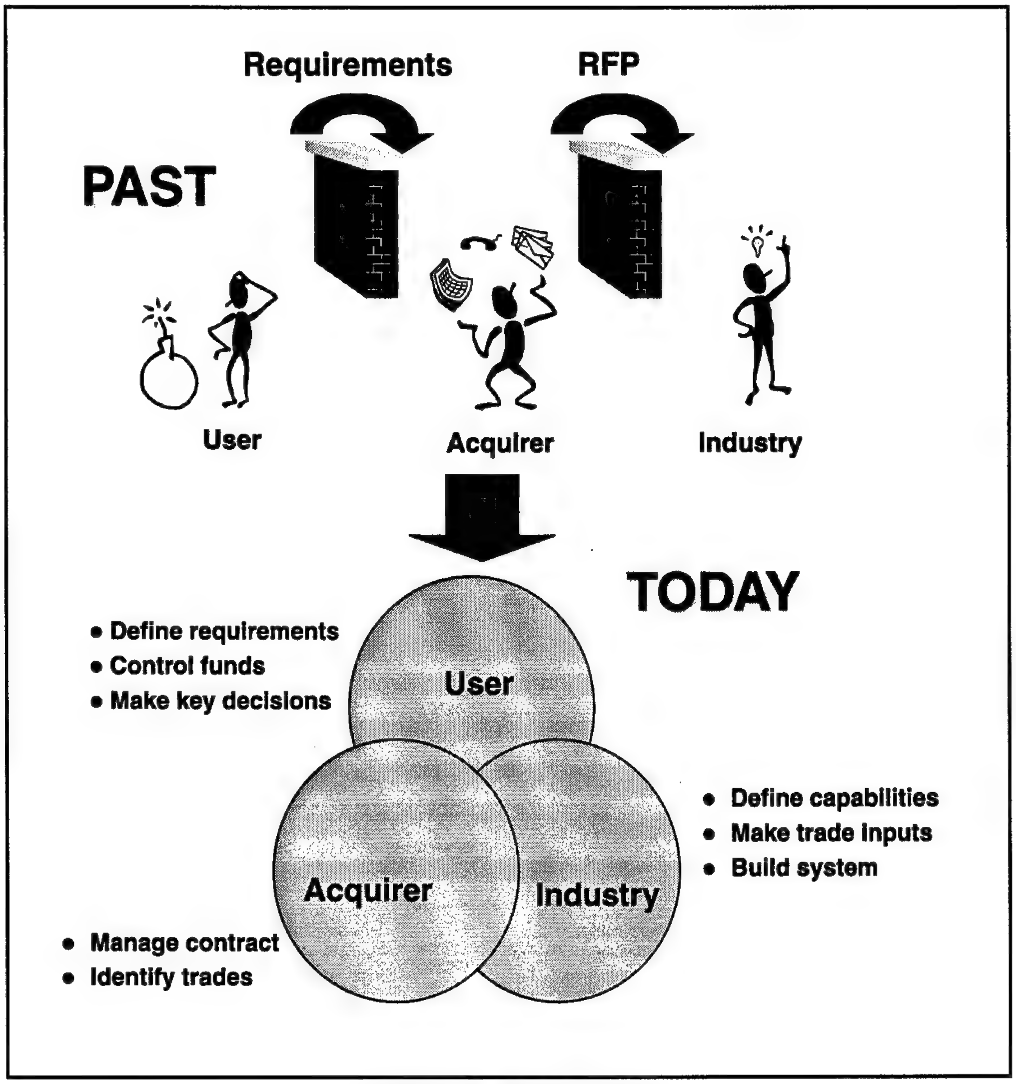

Figure 4. Partnering

PARTNERING

We can no longer allow the sequential, isolated approach to developing systems! CAIV relies on partnered management of the trade space between the user, acquirer, and industry participants, including strong involvement from the sustainment experts in each of the three communities.

In the past, the all-too-common process flow was sequential, with limited partnering. Under CAIV, the user defines system requirements, with comprehensive input from sustainers. In addition, the acquirer and industry partners support the user by identifying and quantifying the major risks and TOC drivers, thereby enabling better informed decisions. The acquirer leads system development, with

strong user and sustainer involvement on potential trades identified by the acquirer or industry. Industry, under contractual incentives, allocates requirements and designs systems for minimized TOC, seeks lower cost and equally capable aternatives for system elements under its control, and makes recommendations for elements not under its control (based on trade studies).

A key element in CAIV success will be the cost performance integrated product team (CPIPT). The CPIPT will complete cost-performance-schedule tradeoffs leading to CAIV-based cost, performance, and schedule objectives. The CPIPT, to include the user, must work closely together to agree on final threshold and objective values for cost, performance, and schedule parameters in preparation for the milestone decision and completion of key documentation.

CAIV-based threshold and objectives for KPPs, life-cycle cost targets, and critical milestones become the core drivers for the subsequent program. These core parameters must be consistent across the ORD, acquisition program baseline (APB), acquisition strategy, and test and evaluation master plan (TEMP) that come together beginning with MS I. The IPT and CPIPT remain active through-out the program life cycle up through Phase III, production, fielding and deployment, and operational support. The CPIPT is the cognizant group to continue CAIV-based cost-performance-schedule trade-offs, to establish cost range objectives for production and sustainment, and to revise performance, cost, and schedule objectives prior to each milestone decision.

After MS I, the contractor should be a major contributor for CAIV-based analyses and tradeoffs. Solicitations need to address life-cycle cost and performance objectives and request industry's approach for implementing and managing the CAIV process. The contractor and government managers should give consideration to establishing a co-chaired hierarchy IPT structure. Working level IPTs, formed around critical subsystems, report to a management IPT through a systems integration IPT.

The core of the CAIV process is tradeoffs conducted by the working level IPTs. Working level IPTs should be given a cost target and chartered to conduct cost-performance tradeoffs to reduce subsystem cost drivers. Cost-performance tradeoffs at the system level depend directly on subsystem level cost and performance tradeoffs. The number and focus of IPTs will change as the program matures from development into production and operation and sustainment.

"CAIV relies on acceptance of higher risk to aggressively pursue a "best value" system for the user."

CAIV relies on acceptance of higher risk to aggressively pursue a "best value" system for the user. Contractors and IPTs should be given incentives to conduct effective and meaningful cost performance tradeoffs.

The contractor is key in cost-performance trades. The contractor-government partnership, in which the customer employs prudent risk management and participates fully in the development of the confidence needed to entrust weapon system development, ensures the success of the contractor's cost-performance trades.

This partnership is the natural evolution of the insight-oversight paradigm.

Promotions and assignment policies must recognize and reward successes and best efforts. Cost-type contracts should include an award fee clause that shares cost savings between the government and contractor. Incentives were a key ingredient in the Peace Shield program's total success in meeting aggressive schedule and performance requirements.[1]

The contractor shared 40 percent of a $50 million incentive bonus with employees. The incentive, combined with an integrated earned value-metrics-schedule system, superb partnering with the acquisition office and customer, and aggressive software management, overcame an early schedule deficit to deliver a validated system six months early.

There are many tools available to motivate contractors: competitions between primes, competition at the component breakout level, award fees, award terms, performance bonuses, value engineering opportunities, and multiyear or sole-source awards. Acquisition offices should address incentives as part of the CAIV plan included in the acquisition strategy. Contractors must be encouraged to meet and exceed life-cycle cost reduction targets, not just near-term cost objectives.

"Promotions and assignment policies must recognize and reward successes and best efforts."

In order to address life-cycle costs up front and early, for example, continuation of a multiyear contract can be tied to reaching or exceeding interim life-cycle cost targets. The contractor could receive a larger percentage of the next production lot or could be awarded the next phase if production unit costs meet or exceed a cost reduction profile. The objective should be to tie life-cycle cost targets and contractor performance together through innovative and aggressive incentives.

TOC/LCC Focus

CAIV requires all team members maintain focus on TOC/LCC. Fiscal constraint is a reality that all Air Force stakeholders must recognize. Based on the determination of resource availability, stakeholders must set an aggressive but realistic TOC target for the system.

At each milestone, decision makers will review targets and progress toward verifying that they will be met. Cost targets shall be addressed in the acquisition strategy and will be included and tracked in the acquisition program baseline (APB). CAIV-based cost targets should be included in requests for proposals (RFPs) and contractors given incentives to achieve cost targets. Also, all personnel must constantly be cognizant of the need to identify cost reduction opportunities and tradeoffs.

Typical targets for procurement and sustainment are average unit procurement cost (AUPC equals total procurement funding/total quantity) and average unit O&S cost (AUO&SC equals unit cost per flight hour, etc.). Each of these metrics can be tailored to the specific system. Procurement targets can be expressed as a cost profile; for example, AUPC versus production lot number. Sustainment targets may be expressed as a percentage reduction relative to O&S costs of a similar system.

Confidence limits for development, procurement, and sustainment cost targets will vary with the phase of the program as well as system complexity and the degree to which it is pushing the state of the art. At MS I, for example, development cost estimates should be more accurate than estimates for O&S costs.

Estimating TOC/LCC poses a significant challenge early in the program, especially for cutting-edge programs. In addition, government and industry have sometimes had large variances in cost estimates, leading to program start complications. SAF/AQ has sponsored a cost estimating reinvention team to address some of these challenges.

Unfortunately, TOC/LCC focus may well be the weakest link in the CAIV process. The reality is that instant-year dollars are politically and practically the driving factor in program decisions. It is easy to say decision makers must make decisions based on TOC considerations, but a lot harder to manage real programs that way. When we see high payoff investments rejected in our programs, it seems we often manage by the "modified Wimpie philosophy," which is not, "I will gladly pay you on Tuesday for a hamburger today," but "I will gladly pay you for three hamburgers on Tuesday for a hamburger today!" While we may bemoan such an approach, we must realize that without the hamburger today, we may starve and not reach Tuesday! The only way we can overcome this malady is with more accurate, believable tradeoff data, so that decision makers will have a better picture of the true impact.

RISK-BASED MANAGEMENT

Risk management is an integral part of CAIV. It recognizes we cannot afford to avoid all risk, but rather must manage the critical risks. A comprehensive and disciplined risk management program throughout a program's life cycle is critical to effective management to meet cost, performance, and schedule.

As established by DoD 5000.2-R (DoD, 1998) and AFMCP 63-101, the risk management program identifies and tracks risk drivers, generates risk-handling plans, and provides for monitoring to track risk "retirement" or growth. Risk reduction measures are included in cost-performance tradeoffs, where applicable.

Program partners must jointly identify, analyze, and prioritize critical program risks, then periodically review handling plan progress. Handling approaches can run the gamut from developing alternate designs for critical components to simple monitoring to ensure a risk does not take root and grow. A commonly used tool for identifying and prioritizing risks is shown in Figure 5.

"The reality is that instant-year dollars are politically and practically the driving factor in program decisions."

The risk matrix helps identify the risks that must be addressed—those that have high probability of occurrence and potential high impact. Risk management is not just an engineering function! The team must address programmatic risks and all functions must be involved in the handling

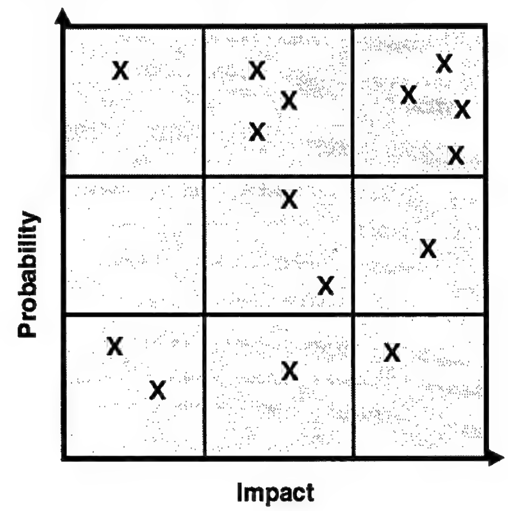

Figure 5. Risk Matrix

plans as appropriate. In fact, any program element associated with cost, schedule, and performance has a direct interface with the risk management process.

It is important to remember that risk management is used throughout a program's life cycle. A risk management plan should be part of the early CAIV strategy. Several programs have reaped benefits by conducting government-industry risk brainstorming and prioritization sessions that directly influenced the RFP (e.g., Space Lift Range Modernization and Satellite Control Network programs). RFPs should require offerors to identify their risk management approach, risks inherent in their design, and risk handling plans.

MEASUREMENT

Setting realistic but aggressive goals for cost and performance is a key element of program management. Measuring progress toward attaining those goals is a challenging but critical element of CAIV implementation. Proper metrics will add value by aiding decision making rather than simply reporting status. Metrics measure a wide range of parameters, including health of critical processes, effectiveness of cost saving initiatives, and status of the "value stream."

The earned value management system (EVMS) and technical performance measurements (TPMs) provide particularly useful metrics. A contractor needs an EVMS to manage complex tasks. Proper partnering will provide government offices insight into the EVMS. TPMs are product design and performance assessments that estimate values of essential performance parameters of the current design. TPMs assist in determining the potential impacts of differences between planned and actual values. Table 1 lists other useful metrics and tools.

Table 1. Illustrative CAIV Metrics and Features

Are cost objectives defined and consistent with requirements programmed and projected fiscal resources?	• Out-year resources identified? (dollars) • Production and O&S cost objectives included in the RFP? • Key tradeoff issues addressed (e.g., in AoA)?
Is the government managing to achieve cost objectives?	• RFP contains a strict minimum number of performance specifications? (number) • CPIPT functioning, tradeoff space identified in program baseline and RFP? • Risks to achieve cost objectives identified and program steps to address these defined? (risk plan) • Incentives for achieving life cycle cost objectives included in the RFP and contract? (percent relative total contract dollars; period of performance tied to life cycle cost target profile) • Mechanism for contractor suggestions to reduce production and O&S costs in place and operating? (value engineering clause) • Allocation of cost objectives provided to IPTs and key suppliers • Measurement and estimation of reliability and maintainability • Robust contractor incentives plan in place?
Are contractors managing to achieve cost objectives?	• Provide appropriate tools for cost-performance tradeoffs (including incentives) and participate in cost-performance tradeoff process (hierarchy IPT structure; award fee flow down to IPT members) • Identifies and implements new technologies and manufacturing processes that can reduce costs • Identifies procedural/process impediments to cost reduction measures • Establishes strong relationship with vendor base, including sound incentives structure

These examples reflect the degree to which a program is structured for CAIV success. They provide important and observable tools that assist in setting aggressive production and operating and support (O&S) cost objectives and management of the program. In some cases, quantitative metrics can be defined as indicated by the parentheses at the end of a process step.

CAIV Evolution Through the Life Cycle

CAIV is initiated at the beginning of a program and evolves through the life cycle. As an acquisition methodology, the application of CAIV varies between each acquisition phase as performance requirements, initially established as a range between required thresholds and desired objectives, narrow as a program migrates toward production. Let's briefly examine the application of CAIV across an acquisition life cycle using the CAIV tenets.

Phase 0

In Phase 0, CAIV supports the analysis of alternatives (AOA) by focusing on KPPs and cost drivers. The R-TOC process provides essential tools with data from existing systems and techniques for baselining cost drivers. At the end of this phase the ORD is established with threshold and objective ranges, funding is assigned for development (where necessary), and a maintenance strategy is proposed to minimize long-term O&S. Unfortunately, current practice provides a detailed ORD, usually based on mission effectiveness analysis, without adequate assessment of TOC impacts.

"CAIV is initiated at the beginning of a program and evolves through the life cycle."

Requirements. The highest Air Force levels ensure that defense system effectiveness is optimized within constraints of available and projected resources. Also, warfighters and users utilize mission effectiveness and cost performance analyses as key parts of the AoA. When the preferred approach is identified, users employ mission effectiveness analysis and CAIV principles to set initial weapon system requirements, based on the best insight available to total ownership cost (TOC). As a result, ORD I should include TOC objectives.

Partnering. The warfighter and user lead the requirements definition efforts, and should have acquirer support if an existing program office or a development planning core team is assigned.

TOC focus. The Phase 0 IPT focuses on the life-cycle aspects of a program by developing and recommending an operation and sustainment (O&S) strategy that will optimize the elements of reliability and maintainability. TOC focus recognizes that the majority of life-cycle cost is in the O&S phase, and the resulting strategy will reflect a system that both maximizes system reliability and requires minimum downtime to fault, isolate and repair problems.

Risk-based management. As much acquirer involvement as possible is desirable to support the user in gaining an early understanding of potential risks and handling alternatives. In preparation for Milestone 1, the acquisition strategy must

identify the key risk areas within the proposed solution. These will become integrated into the CAIV strategy and, ultimately, the RFP.

Measurement. Objective TOC should be set in the ORD. The requirements "owner" should estimate which requirements are likely to be cost drivers; and for each such driver, track whether adequate TOC insight has been gained. This is hard! For that reason it is essential that users work with financial experts within acquiring agencies to best estimate total ownership costs.

PHASE I

Maximum leverage for CAIV efforts exists in Phase I, since system design has not yet been finalized.

Requirements. During Phase I, the weapon system IPT uses CAIV to define TOC impacts and conduct trade studies focused on design, particularly as influenced by O&S. Tradeoff data enables warfighters and users to refine requirements.

Partnering. The team now typically includes an acquisition program office and at least one contractor. The acquirer will have the lead for completing PDRR, but must ensure close coordination with the user. Using CAIV, the team should baseline expectations through the following steps:

- Identify common and unilateral objectives to ensure concerted, focused effort.

- Define all interdependencies and organize, plan, and commit to act to meet them. Central to this aspect is analysis of the contractor's network and critical path, and integrated master plan (IMP). Based on this analysis, the government should build its own IMP to ensure government action meets timelines expected by the contractor and does not give any cause for contractor claims.

- Generate a unified risk handling plan.

- Develop a concept of operations (CONOPS) to define management and working level interaction, metrics, etc.

TOC focus. With a funded and manned program, adequate effort can now be expended to identify TOC and risk impacts from design and sustainment trade studies.

Risk-based management. The team should generate a unified risk-handling plan to address high and moderate risk areas. The plan should consolidate previous risk analyses, conduct further brainstorming, prioritize risks, allocate risk-handling responsibilities, and regularly review status. Implementation may include provisions in acquisition strategies, contracts, or parallel efforts. As a minimum, the contract should require the contractor to conduct trade studies to identify trade space.

"The team should generate a unified risk-handling plan to address high and moderate risk areas."

Measurement. The team must continue to track TOC estimates to TOC objectives. In addition, requirements "owners" should continue to track degree of insight to TOC impact for each identified cost driver. The team should track risk

drawdown per the handling plans with metrics tied to specific risk reduction accomplishments. Use of TPMs can be very effective for such effort.

Phase II

Early in Phase II, system design freeze limits the ability of CAIV to generate further substantial cost savings. However, focus on producibility and O&S may still yield benefits.

Requirements. The IPT uses CAIV to ensure requirements are met at minimum TOC.

Partnering. The team may expand to include other organizations (e.g., AFOTEC). The same principles of teaming apply as applied in Phase I.

TOC focus. Tradeoff studies will focus on manufacturing and sustainment impacts on TOC and risk. A mature design and testing of components and prototypes should enable more accurate estimates of O&S impacts on TOC.

Risk-based management. The contract again requires trade studies to identify the "trade space," although the ability to make substantive changes decreases as the design matures. The team should employ the same type of risk program definition as described in Phase I.

Measurement. The team continues to track TOC estimates to TOC objectives and risk drawdown through TPMs. In addition, the contractor EVMS, in conjunction with the integrated master plan (IMP) and integrated master schedule (IMS), provide accurate status for completion of development as well as visibility to any potential problems before they get out of hand. Data from prototype and component builds and testing will support production cost estimates. The team will have determined the availability and visibility of such metrics during their partnering sessions.

Phase III

In Phase III, CAIV can generate TOC savings through production improvements prior to delivery of finished systems to the user. For fielded systems, the R-TOC process is primary in identifying cost-saving opportunities, but the CAIV process really starts all over again in support of system modifications.

Requirements. The IPT ensures continued ability to meet baseline requirements while adapting to requirements evolutions that drive system modifications.

Partnering. Although some partners may have changed from earlier phases (especially if major modifications are in process), the same principles apply.

TOC focus. With an eye on reducing immediate costs, contractors are given incentives in production contracts to streamline manufacturing processes to reduce the cost of producing systems. Additionally, all members of the IPT, especially maintainers, work to ensure proposed sustainment processes and practices, maximize system availability, and minimize cost.

Risk-based management. For steady-state systems, teams should focus on risks that may upset the steady state. Risk occurs in all phases of acquisition and it is constantly monitored and re-examined to ensure old risks are managed and new risks are identified.

Measurement. As in previous phases, a well-functioning EVMS along with manufacturing IMP and IMS provide the IPT the necessary information to assess program progress and status.

Hybrids

Most acquisition programs consist of modifications and ACAT III acquisition efforts. One of the most innovative aspects of the revised acquisition regulations is the recognition that these systems do not need to go through the classic Phase 0, I, II sequence before being fielded. In such cases, the IPT should review the above guidance and synthesize or tailor to the program at hand. As part of the CAIV process, IPTs are encouraged to minimize acquisition times and costs by streamlining the acquisition processes wherever and whenever possible.

Conclusion

CAIV is a viable concept for attaining R-TOC objectives. CAIV and the Air Force R-TOC process go hand-in-hand: CAIV primarily applies to systems in acquisition and the R-TOC process applies to fielded systems. Much of the CAIV construct described here is not new. Parts of it have been applied in numerous programs. The authors, and many other program managers, really used key elements of CAIV before they knew it *was* CAIV. The construct presented here offers a more integrated, definitive CAIV implementation description than has previously been available. In fact, the CAIV construct presented is more a program management construct than pure CAIV.

Challenges to realizing the benefits that CAIV offers still exist. The greatest challenge is the need to make decisions based on future impacts to break the paradigm of continuously mortgaging the future when faced with the reality of the critical exigencies of today. That paradigm leads to Under Secretary of Defense (Acquisition and Technology) Jacques Gansler's "death spiral" (1998). Improved understanding and believable quantification of TOC impacts is critical to overcoming that fate. The key targets to enable better information for our decision makers fall along the lines of the CAIV tenets:

- an improved requirements process to focus on capabilities-based requirements supported by TOC impact data;
- improved, partnered management of the trade space;
- recognition by every member of the user, acquirer, and contractor team that they have an R-TOC role (in addition, improved cost estimating capabilities in government and industry);
- improved understanding and implementation of risk management;
- better metrics;
- integrating all CAIV aspects for effective program management; and
- training users, acquirers, and contractors at all levels on CAIV implementation so that CAIV becomes ingrained in the culture.

Finally, CAIV as a term of art should disappear in the future—but everyone should do it! In 1991, a senior-level government-industry team addressed the problem of excessive engineering change proposals in development by defining Clear Accountability in Design (CAID). CAID determined that the government

would not take configuration control below the "A Spec" until generally after physical configuration audit. Most people in acquisition today cannot identify CAID, but it is the standard. CAIV should go the same way.

David R. Graham is a program analyst in the Air Force Deputy Assistant Secretary's Management Policy and Program Integration Division. He began working for the Air Force in 1979 at the Space & Missile Systems Center (SMC), Los Angeles AFB, CA, and has held a variety of budget, cost performance, cost estimator, and program analyst positions up to the present.

(E-mail address: David.Graham@pentagon.af.mil)

Allen L. Gotwald is a systems engineer working at the Air Force Materiel Command's Engineering and Technical Management, System Engineering Policy Division, at Wright-Patterson Air Force Base, OH. He worked for 7 years within the F-16 program office where he served as lead engineer on the development of mission planning systems and later served as the lead engineer for the F-16 Block 50 program. In 1997 Gotwald was selected as an engineer within the Centralized Acquisition Support Team (CAST) at the Air Force Material Command Headquarters. He later became the co-director for CAIV implementation across the command, helped with the development of the Reduction in Total Ownership Cost (R-TOC) Guide, and developed an implementation workshop for the Integrated Master Plan and Integrated Master Schedule (IMP/IMS). Gotwald holds an M.S. degree in engineering management from the University of Dayton.

(E-mail address: allen.gotwald2@wpafb.af.mil)

Colonel Michael A. Kaye, U.S. Air Force, is the chief of the Acquisition Support Team at the Space and Missile Systems Center (SMC), Los Angeles Air Force Base, CA. He recently headed an Assistant Secretary of the Air Force for Acquisition (SAF/AQ)-sponsored reinvention team focused on boosting CAIV and Sustainment in the requirements process. Prior to assuming his current position, Kaye served as Deputy Program Director of PEACE SHIELD, a $5 billion Command, Control, and Communications (C^3) system installed in Saudi Arabia, which received the 1994 John J. Welch, Jr., Award as the top Air Force program. He holds an M.B.A from Hardin-Simmons University, M.S. in engineering science from Purdue University, and B.S. in physics from the University of Illinois.

(E-mail address: Michael.Kaye@losangeles.af.mil)

Lt Col Mark S. Sobota, USAF, is currently assigned to the U.S. Special Operations Command (USSOCOM) as Chief, Aviation/Space Operational Test and Evaluation Branch at USSOCOM Headquarters, MacDill AFB, FL, and previously served at the Electronic Systems Command, Air Force Flight Test Center, and Air Force Research Lab covering a variety of weapon systems from Joint STARS, LANTIRN, F-16, B-1B, F-15E, and conducted advance research for the F-22. He is a graduate of the Defense Systems Management College's APMC 97-3, received a B.S. degree in chemistry from the Virginia Military Institute, and a B.S. degree and M.S. degree in aeronautical engineering from the Air Force Institute of Technology.

(E-mail address: sobotam@socom.mil)

ENDNOTE

1. The contract bid was a $1.1 billion effort for control software, integration, test, and operational activation of the $5 billion command, control, and communications system for integrated air defense of Saudi Arabia.

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APPENDIX

RISK MANAGEMENT APPROACH

Let us consider an example of a potential risk management approach. Typically, system weight is a critical parameter that will impact total system performance. Assume that keeping weight under the allocated threshold is particularly vital, as it usually is. Numerous studies have also shown that weight typically grows through development of a system. Figure 6 shows an allocated threshold along with "uncertainty bands" that narrow as the design matures. Clearly, a tested, validated system at Milestone (MS) III should be distinctly characterized. However, at Milestone I, a "paper design" only estimates system weight. Assuming the weight Technical Performance Measure (TPM) will be regularly tracked, we can define four regions on the chart that the TPM may be in.

I: Weight well below threshold; high confidence system will meet threshold at MS III.

II: Weight below threshold; the closer to the threshold, the more active efforts must be to contain growth.

III: Weight above threshold; need aggressive weight reduction program.

IV: Weight well above threshold; low probability to meet threshold even with aggressive program.

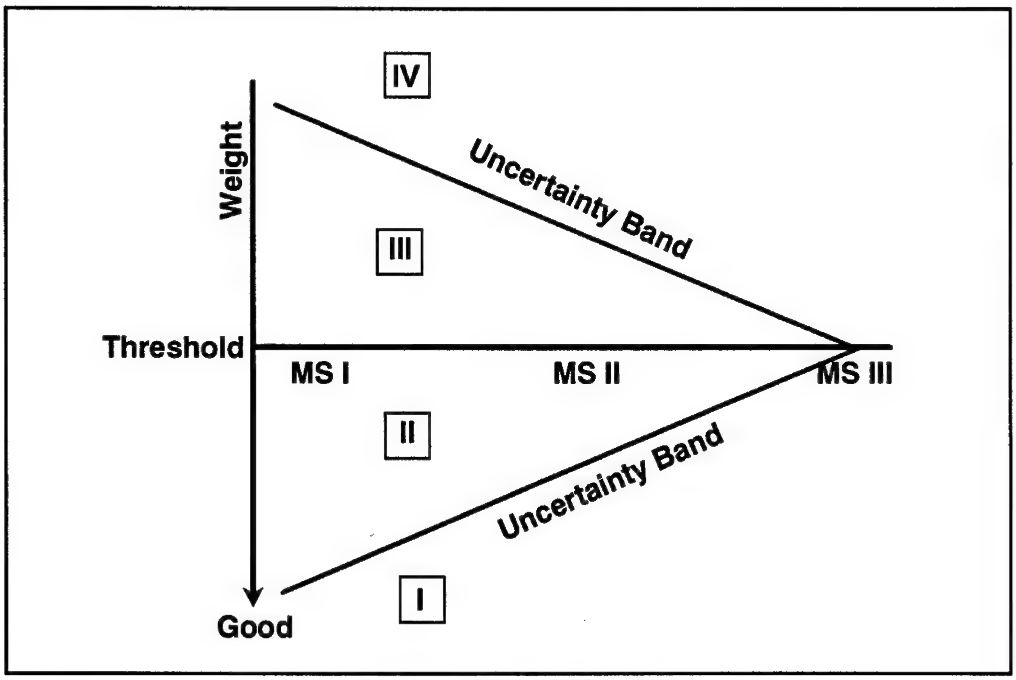

Figure 6. Managing Risk

Cost Driver Calculation

Figure 7 is a simplistic view of a "comb chart" analysis of cost drivers for a system. The costs are divided into RDT&E, procurement, and O&S. Each is further subdivided into WBS elements. Such subdivision should go down as far as practicable. For each element, dollar estimates and percentages of TOC are generated. This analysis will provide a baseline against which R-TOC efforts are compared. Currently, SAF/AQCT is coordinating 10 Air Force pilot programs using this methodology to generate R-TOC plans and associated objectives. We anticipate that this procedure will be directed on almost all programs in the future.

Directions for conducting such analysis are in the R-TOC Guidebook previously cited.

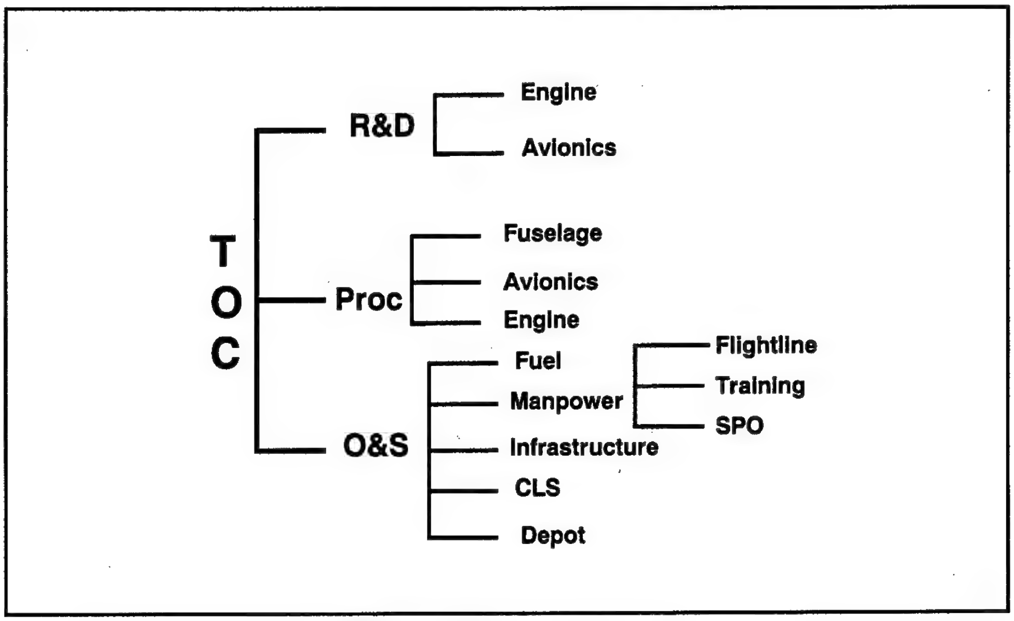

Figure 7. Cost Drivers

PARTICIPATORY CONTRACTING

William N. Washington

Participatory contracting represents a philosophy in which the government attempts to involve outside entities in a form of partnership or coordinated effort, with the goal either of reducing costs or improving performance; private industry seeks to increase profits and have greater control over the effort. This win-win scenario can thus appeal to all participants, and makes administration of the contract more of a partnership effort, for its success benefits all the participants.

Over the past several years, the federal contracting world has seen several changes, as the government has attempted to modernize practices and find innovative ways to improve on the procurement process. One of these trends, which I shall term "participatory contracting," is to involve entities outside the government in a form of partnership or coordinated effort. Four types of general contracting seem to fall into this type of arrangement: partnership agreements, cooperative research and development (R&D) agreements (CRADAs), share-in-savings (SiS), and research tournaments.

PARTNERSHIP AGREEMENTS AT DEPOTS

This is part of a continuing change in function for the depots, in that the depots are currently seeking outside work in order to better utilize existing facilities, and thus reduce costs. This is in keeping with recent Department of Defense (DoD) guidance to promote commercialization of military depots ("Maintenance of Military Equipment," 1996), and is also discussed in a Government Accounting Office (GAO) Report (1998). Further, these types of arrangements are legal under Title 10 of the *United States Code.* Generally, these efforts have fallen under four types of arrangements, which are valued at about $500 million annually (Cahlink, 1999):

- direct sales (the government facility acts as a subcontractor for private industry);
- workshare (the program manager sends funds directly to the depot for part of the work, and contract is awarded to private industry for the remaining portion);
- directly contracting out the repair of military equipment to private industry,

where the depot and private industry form a team effort; or

- leasing the space or facilities at depots to private industry.

These partnership agreements portend the future for depot facilities and usher in the concept of "commercialization" of these facilities, which in turn has the potential to provide both small and major defense firms with several benefits, such as:

- applied engineering programs;
- advanced manufacturing knowledge; and
- state-of-the-art laboratory or manufacturing resources.

These efforts further bring to the depots outside work and money that would lower the depots' costs by fully utilizing existing personnel and facilities. Further, through working with other government and Service programs (such as the CRADAs mentioned below) they can promote technology transfer and areas of science, of interest to the military, supporting both these programs and the depots (Washington, 1999).

Cooperative R&D Agreements

Cooperative R&D agreements (CRADAs) have been used for teaming or technology transfer projects with small businesses, universities, and government laboratories.

Teaming and technology transfer projects can involve commercial work only, projects with technology transfer incubators (TTI), small business innovation research (SBIR), and small business technology transfer (STTR). These approaches can serve as a bridge between commercial, government, and university R&D and production applications (Washington, 1995). They can also incorporate existing federal, state, and local funding initiatives which promote small businesses (in 1988 this represented $550 million to promote technology innovation [Peterson, 1993]) to help provide funding for the projects. These approaches can tie into the Services' Centers of Excellence Programs or the Office of the Secretary of Defense-funded university research initiatives.

Further, these programs have been expanding somewhat to now also include joint university-industry research projects (Gaumond, 1994). The Advanced Research Projects Agency (ARPA) also funds engineering programs through its technology reinvestment project (TRP) initiative, in conjunction with the National Science Foundation (Wax, 1995). Through these programs, the Services have leveraged the best universities in the nation to advance the state of science in areas of interest to the military (and also provide external funding for those same projects). These approaches are thus a win-win scenario for new technologies, in that they promote the growth and development of new firms or universities, and provide additional research and development on technologies of interest to the military at reduced costs (being partially subsidized by federal, state, and local funding).

Share-in-Savings

Another type of initiative contracting represents a variation on the value engineering change proposal (VECP) theme, which is similar to the gain sharing approach used in private industry. The Share-in-Savings (SiS) instrument was a product of the National Defense Authorization Act of Fiscal Year 1996, titled "Share-in-Savings Pilot Programs" (1998). The program allows for the use of saved monies from government accounts to reward a contractor(s) for successful programs and procedures that enable the government to save money. The use of SiS in government outsourcing is relatively new, and since it has only been approved for limited information technology pilot projects (10 projects between \$25 million and \$100 million, and another 10 projects between \$1 million and \$5 million), it has not received much attention.

So far, three projects have received Office of Management and Budget (OMB) approval for an SiS pilot program: the Department of Energy's "Energy Savings Performance Contracts" (1998); the National Aeronautics and Space Administration's "Shared Savings Clause" (1998) used for the modernization of their headquarters' computer networking; and the General Services Administration's "information technology projects" (Frank, 1999). The premise behind SiS is to allow a contractor to share in either internal or collateral savings that have been generated as a result of the contractor's actions; similar to a VECP. However, SiS can operate on a higher funding level, both in terms of the absolute dollars that can be awarded (\$100 million), and in terms of not being limited to internal savings from a specific department or program. In this type of program the contractor makes the capital investment needed to execute the initiative, then shares substantially in the savings that are derived (i.e., under current initiatives up to 50 percent).

An additional feature of this type of program, unlike VECPs, is that actual savings to the overall agency can be used for the award payments to the contractor, unlike the normal fiscal rules, where those savings would have to be returned to the general treasury. This feature can be a definite advantage in some circumstances, and has been much sought after by program managers for the past several years. Similarly, at about the same time as SiS was approved, Dr. Kenneth Oscar, Deputy Assistant Secretary of the Army (Procurement), suggested an "Acquisition Reform Incentives Clause" (1996). This clause represents a variation on the VECP theme for use on nonhardware item contracts. It would work like a VECP proposal, but reflects the larger percentage savings (based on a five-year reward payout schedule) typified in the SiS initiatives, with a slightly different but appealing wrinkle, that the contractor's percentage payment would decrease over time.

"The [Share-in-Savings Pilot Program] allows for the use of saved monies from government accounts to reward a contractor(s) for successful programs and procedures that enable the government to save money."

Research Tournaments

Research tournaments (Fullerton, 1995; Taylor, 1995; Washington, 1997) represent a competition process that is structured like an auction, with the winner awarded a "prize" for the best product. The auction component consists of the participants paying a fee for entering the tournament, which could be used to defray the cost of the prize, or offset the cost of conducting the competition.

"This process promotes innovation on the part of the offerors, and provides firmer cost estimates for equipment, since costs are based upon completed hardware and not conceptual hardware estimates."

The government commits to pay the research tournament winner a set amount that is verifiable by the courts, and must be awarded. The selection of the winner would be based upon specified priorities (e.g., performance or cost) established by the government, which would be specified in the request for proposal, so that the competing firms would know which innovations or priorities were most important in winning the prize. Finally, each firm would submit its prototype at the end of a specified period of time, for the government to evaluate and subsequently award the prize for the best product. Thus, the competition would differ from a patent competition, in that it would select the most innovative design across a group of offerors that would win, with the quality of the design stressed over the date of discovery.

This process promotes innovation on the part of the offerors, and provides firmer cost estimates for equipment, since costs are based upon completed hardware and not conceptual hardware estimates. Rich and Janos (1994) also point out that the "beauty of a prototype is that it can be evaluated, and its uses clarified, before costly investments for large numbers are made." This is also in keeping with DoD Directive 5000.1 (1996), which stresses modeling and simulation of new systems.

An additional benefit of this type of procurement is that it should require less government oversight, since the offeror has already developed the item, and is offering it at a fixed price to the government. Thus, concerns about overseeing development and production costs are negated. Finally, as mentioned above, the contractors could specify along with their proposals what they consider to be appropriate rewards or fees for additional or alternative performance goals. This would allow the source selection authority to perform up-front tradeoffs and assessments. To date, the author has not seen any research tournaments used by any of the Services, but the National Academy of Engineering workshops have recently endorsed the concept (National Academy of Engineering, 1999).

Summary

These various types of contracting afford both the government and private industry significant benefits. For the government, they offer the potential for reduced costs and improved performance; private industry receives the potential for

increased profits and more control over those projects. This win-win scenario can thus appeal to all the participants, and makes the administration of the contract more of a partnership effort, for its success benefits all the participants. Further, while each of these different contracting vehicles approaches this partnership process from a different perspective, they all attempt to seek optimum performance through assigning the work in the "best division of labor" between the government and outside agencies to achieve their shared goals.

William N. Washington is an operations research analyst with the Office of the Deputy Chief of Staff for Resource Management, HQ CECOM, Fort Monmouth, NJ. He has a B.S. degree from Kansas State University and an M.S. degree from Trinity University. His doctoral studies were in Measurement, Evaluation and Research Design at Michigan State University. He is a graduate of the Army Acquisition Corps Senior Service College (1995), and the Advanced Program Management Course (96-2). He has received the Secretary of the Army's Award for Outstanding Achievement in Material Acquisition (1994), two DoD Outstanding Paper Awards from DoD Cost Analysis Symposiums (1998 & 1999), three Assistant Secretary of the Army (Financial Management & Comptroller) Author of the Year Awards (1997, 1998 & 1999), a DA Commander's Award for Civilian Service (2000), a DA Achievement Medal for Civilian Service (1998), and the Army Materiel Command's Cost Analysis Award for Modeling (1988). Over the past several years, he has authored several journal articles on acquisition topics ranging from education/training to contracting issues and cost savings. A member of the Army Acquisition Corps since its inception, he is certified at Level III in Program Management; Business, Cost Estimating and Financial Management; and Systems Planning, Research, Development and Engineering. A reference citation for Mr. Washington also appears in both *Who's Who in America (2000)* and *Who's Who in the East (1999)*.

(E-mail address: William.Washington2@mail1.monmouth.army.mil)

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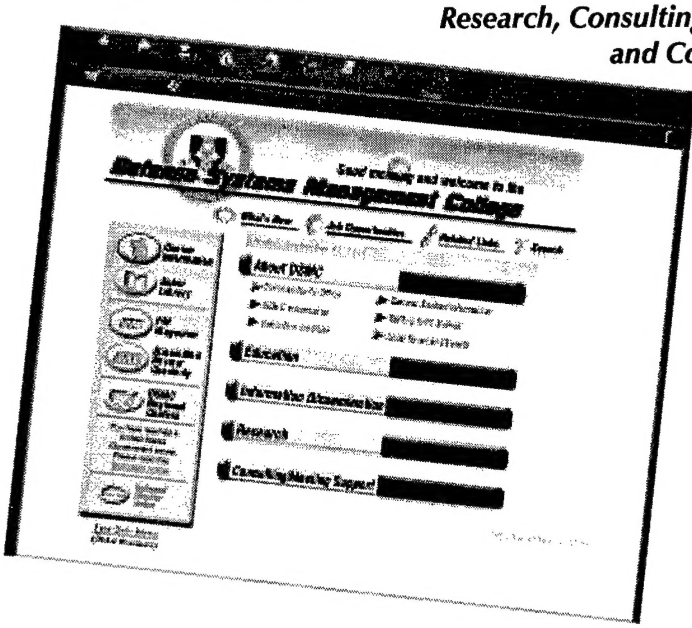

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- Learning Resource Center
- Past Performance
- Program Management
- Regional Centers
- Registrar

Information Dissemination
- Acquisition Events
- Best Practices
- Lessons Learned
- Links to Related Sites
- Manufacturing Resources
- Past Performance
- Publications
- Services

Research
- Acquisition Events
- Best Practices
- Lessons Learned
- DSMC Military Research Fellows
- Overview/Projects
- ROAR

Consulting/Meeting Support
- Consulting Services
- MDC/Group Services
- Acquisition Reform Learning Model

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